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OF

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CONTENTS OF VOL. XXXV.

GENERAL MEETINGS.

The Institution of Mining Engineers.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

[redacted]

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS AND THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

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THE MINING INSTITUTE OF SCOTLAND.—*Continued.*

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THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

APPENDIX.

APPENDIX.—*Continued.*

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ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, *e.g.*, "ANNUAL REPORT," "LIST OF MEMBERS," ETC.

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TRANSACTIONS

OF

THE INSTITUTION

OF

MINING ENGINEERS.

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE PHILOSOPHICAL HALL, LEEDS, FEBRUARY 4TH, 1908.

MR. WILLIAM WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBERS—

Mr. THOMAS LOWDEN, Mechanical Engineer, 85, Kirkstall Road, Leeds.

Mr. GEORGE HENRY RAYNER, Engineer, The Hardy Patent Pick Company, Limited, Sheffield.

ASSOCIATE MEMBERS—

Mr. PHILIP ERNEST BROWN, Architect and Mining Surveyor, Messrs. Stubbs & Brown, 74, High Street, Sheffield.

The Right Hon. the Earl FITZWILLIAM, Colliery Proprietor, Wentworth Woodhouse, Rotherham.

Mr. ERNEST SUTTON, Explosives Merchant, 22, Victoria Chambers, Leeds.

Mr. TOM TAYLOR, Colliery-supplies Merchant, North Terrace, Cross Gates, Leeds.

STUDENTS—

Mr. WALTER ALOYSIOUS DOYLE KELLY, Mining Student, The University, 53, Mount Preston, Leeds.

Mr. RONALD THOMPSON, Mining Student, Stoneleigh, Godstone Road, Rotherham.

Mr. JONATHAN WROE read the following "Notes on a recent Underground Fire at Wharncliffe Silkstone Collieries, and the use of Rescue-apparatus in connection therewith":—

NOTES ON A RECENT UNDERGROUND FIRE AT WHARNCLIFFE SILKSTONE COLLIERIES, AND THE USE OF RESCUE-APPARATUS IN CONNECTION THEREWITH.

BY JONATHAN WROE.

On October 15th, 1907, an alarming fire occurred at an electric haulage plant in the Fenton seam at the Wharncliffe Silkstone collieries, at a point about a mile from the shaft, which might have had very serious consequences had the fire penetrated into any of the workings. In fact, it might have resulted in the stoppage of the mine for many months, with possible loss of life. The fact of the fire having been extinguished without serious consequences does not render the incident less interesting as an object-lesson, and in this connection may be mentioned the following points worthy of attention:—

(1) The risks arising from the use of electrical machinery underground.

(2) The utility of artificial-breathing apparatus in dealing with such fires.

[redacted]

goaf, no wooden bars or props were set. The writer was informed of the occurrence at 12·45 p.m.; he arrived upon the scene about half-an-hour later, and then found that entry to the motor-house was impossible on account of the stifling fumes and great heat. He thereupon issued instructions for the men, who had already been withdrawn from their respective points of duty, to be sent out of the pit by way of the main haulage-road, instead of the return-airway, which was their usual way of exit, but which had become impassible owing to the smoke. An attempt was then made to enter the airway at the back of the motor-house, at A (fig. 3, plate i.), with the view of opening the regulator, B, to admit more air, in order to render less dense the choking fumes. Upon opening the separation-doors, however, this was found to be impossible, and the writer then arranged to fix brattice along to the regulator at B (fig. 3, plate i.). If at this time rescue-apparatus had been at hand, this bratticing would have been unnecessary, and immediate access to the regulator would have been gained. The writer returned again to the motor-house, but found that it was still impossible to enter it. He then despatched a messenger for the rescue-apparatus, Rex fire-extinguishers, and a supply of sand, and also for several of his officials who had been trained in the use of oxygen-breathing apparatus. The telephone, being installed in the engine-house, and access to the same being then impossible owing to the heat and fumes from the fire, the messenger was conveyed in the empty run on the main haulage-road, which is a main-and-tail rope system. On his arrival at the surface, the colliery trap was despatched to the Tankersley rescue-station for the apparatus, which, upon its arrival at the pit-bottom, was conveyed to the scene of the fire by means of the same main-and-tail haulage system.

Meanwhile, the writer was successful in reaching the air regulator, B (fig. 3, plate i.), upon opening which the fumes were slowly dispersed, but it was then possible only to approach near the seat of the fire by crawling; and although strenuous efforts were made to attack the seat of the outbreak, the workmen were continually driven back for want of air. Eventually, however, success attended their efforts, and, by a plentiful use of sand and fire-extinguishers, the flames were extinguished; but it was still found impossible, owing to the intense heat and choking fumes,

to enter the motor-house. About this time, the rescue-apparatus arrived, simultaneously with which the wooden partition doors, E (fig. 1, plate i.), burst into flame, and the outlook again assumed a threatening aspect. The apparatus was immediately put on by two officials, under the supervision of Sergeant Winborn, who had arrived with the apparatus, and who then attacked the flames, being able to approach close to the outbreak and to apply effectively the sand and water and fire-extinguishers, which were handed on by a number of willing workers. The writer's object now was to gain access to the airway in order to ascertain whether the fire had penetrated thither. He therefore instructed the wearers of the apparatus accordingly, who, after having made an examination of the airway, reported that such was not the case. They then made a vigorous attack upon, and succeeded in breaking, the concrete floor of the motor-house, and by means of water gradually subdued the fiery heat beneath, thus ensuring against any further outbreak of fire. This task would have been quite impossible in the absence of any rescue-apparatus.

The helmet type of the Dræger apparatus was used on this occasion, and proved a complete success. Had this apparatus been more readily to hand, the fire would have been extinguished much more quickly than was the case. Considering the position of the rescue-station in relation to the scene of the fire, and the means of communication and transit available, [redacted]

The writer is of opinion that a couple of sets of rescue-apparatus should be kept at the colliery, so as to be immediately available in case of any similar emergency. It would be necessary that they should be exchanged from the rescue-station weekly, to ensure their being always in proper working order. The Wharncliffe Silkstone Colliery Company are of this opinion, as the directors have decided to purchase two extra sets of apparatus, irrespective of the fact that they contribute their quota towards the upkeep of the Tankersley rescue-station. These two sets of apparatus will be installed at the colliery ambulance-station adjoining the pit, which has been fitted up with every convenience necessary for the proper treatment of injured men. The apparatus will be enclosed in a dust-proof case with glass doors, and the ambulance-station attendant, a pit-bank inspector, who is thoroughly competent in the rendering of first aid to the injured, is receiving an elementary course of instruction in the use and care of rescue-apparatus, and will later on be able to put the apparatus on men in the event of any sudden need of such appliances. The apparatus will be exchanged weekly for fresh sets from the Tankersley rescue-station.

Portable electric hand-lamps, with an adequate number of spare accumulators, should also be kept at each colliery, and experience has shown that they should be in regular daily use to give satisfactory results. The writer considers that such lamps should be regarded as an essential part of the rescue-apparatus.

A great deal has been written and said concerning the question of rescue-apparatus, but at present very little has been done towards establishing a system of joint colliery rescue-stations throughout the mining districts of this country; and, although the incident of this fire at Wharncliffe Silkstone colliery was of a small character and, comparatively speaking, insignificant, yet it clearly demonstrates the real value of artificial-breathing apparatus. In this case, it was of material benefit, and enabled an examination to be made which in its absence would have been altogether impossible. The writer is also of opinion that a condition of employment should exist stipulating that all underground officials must agree to undergo a course of training in the use of artificial-breathing appliances, and, in addition, that they should reside within a reasonable distance of the col-

liery at which they are employed, so as to enable them to reach the spot quickly in the case of any sudden emergency. Further, that the full available strength of trained officials should not all be employed upon the same shift, but that their shifts should be arranged so as to enable a certain number of trained officials and workmen to be free at all times, and in readiness for service, if required.

NOTES ON RECENT EXPERIENCE IN THE PRACTICAL USE OF RESCUE-APPARATUS.

BY SERGEANT ARTHUR T. WINBORN.

The writer submits a few notes respecting the use of rescue-apparatus and a consideration of the circumstances under which it was employed in the underground fire at Wharncliffe Silkstone colliery, described in Mr. Wroe's paper.*

(1) The call for the apparatus reached the Tankersley rescue-station, situated a mile from the colliery, about 2 p.m. The message was conveyed by the colliery dogcart, and within five minutes the three sets of Dræger rescue-apparatus were put into the dogcart, and the writer proceeded to the colliery, reaching it in seven or eight minutes, and within about twenty-five minutes the fire, which was situated a mile inbye, was reached. The position of the station in relation to the collieries connected with it is shown in fig. 1.

(2) The men called upon to wear the apparatus did not exhibit the least hesitation in donning it; their confidence in it was absolute, and was confirmed by their experience with it in the foul air and intense heat.

(3) The apparatus was not found cumbrous, and the men were able to do effective work under actual conditions. There was about 4 feet of height in the place where they had to go, and the men complained of no difficulty in breathing, even when excited by the actual presence of danger.

(4) There may be some question as to the relative merits of the helmet or mouth-breathing type of apparatus, but the writer is of opinion that the choice of apparatus is governed entirely by the circumstances under which the wearer has to work, and

* "Notes on a recent Underground Fire at Wharncliffe Silkstone Collieries, and the use of Rescue-apparatus in connection therewith," by Mr. Jonathan Wroe, *Trans. Inst. M. E.*, 1908, vol. xxxv., page 2.

this can only be decided when one is cognizant of the nature of the work to be undertaken. For instance, in dealing with an outbreak of fire much may depend upon the promptitude and energy displayed in attacking the same. It is an occasion calling for sheer hard work and energy, and the helmet type would be

In the case of the fire at Wharncliffe Silkstone collieries, the Dræger helmet was used for the above reasons. The mouth-breathing type may possibly be considered preferable for exploration work, or when men have to travel any considerable distance, as this type may be considered to afford the maximum amount of safety. The area of surface over which an airtight joint has to be made is much smaller, and there is therefore less liability to leakage. It may here be remarked that most men when exerting themselves greatly cannot breathe freely through the mouth only, and the stoppage of the nostrils, and the fact of having the indiarubber mouthpiece securely fastened in the mouth, is a source of discomfort, however well accustomed they may be to the apparatus. Compulsory breathing solely through the mouth is also unnatural. The writer therefore considers that an apparatus which is capable of being used either with the helmet or as a mouth-breathing type possesses decided advantages.

(5) It has been suggested that apparatus should be kept at collieries, and that in the case of the fire at Wharncliffe Silkstone collieries, if the apparatus had been more readily to hand the fire might possibly have been dealt with more quickly; but the writer would point out that the apparatus was on the spot at the seat of the fire at about the same time as the trained men to wear it. The experience that the writer has obtained at the Tankersley rescue-station confirms the opinion that any apparatus which may be kept at collieries must be exchanged at frequent intervals with the apparatus at a rescue-station, in order to ensure its regular use in rotation, and overhauling with the other sets which comprise the station's equipment. The fact that they may be enclosed under glass in a dust-proof case would in no way obviate this necessary precaution. By a strict adherence to this condition, rescue-appliances kept at a pit ready for instant use possess an obvious advantage, provided, of course, that suitable men are at hand to wear them, with a competent man in charge; and, to meet this provision, it would have to be arranged, as pointed out in Mr. Wroe's paper, that the trained men were not all employed upon the same shift, but divided equally, so that they would not all be in the pit at the same time.

(6) Concerning the training of men, the writer would point out that, in order to attain any degree of efficiency in the use of rescue-apparatus, practices at the rescue-station should always take place in a vitiated atmosphere, otherwise they are not of much use. The tasks to be performed should be made to resemble as nearly as possible the actual conditions prevailing immediately after an explosion in a pit, and should include the negotiation of contracted passages, the construction of which should be altered from time to time in order to present a foreign appearance to the men, who would otherwise become familiar with its construction and its difficulties. Bratticing, building brick-stoppings, the setting of props, the use of the different makes of fire-extinguishers, bringing out dummies on improvised stretchers and stretchers proper, and tests of exertion by means of a weight and pulley arrangement, should all be included in station practices. Portable electric hand-lamps, besides being kept at pits, should also be in regular use at the station for practice purposes, provided the means of recharging the same be at hand. It is of the utmost importance that telephonic communication should be available between the rescue-station and the collieries concerned: and it would greatly facilitate the arrival of apparatus at any particular spot if some means of conveyance were always at the immediate disposal of the rescue-station. By way of creating interest and giving encouragement, certificates of efficiency might be awarded to the men upon the accomplishment of cer-

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ination of the actual existing conditions. The workers remained in the black-damp, with the water at times reaching to their waists, for about three-quarters of an hour, and ultimately retired upon realizing their inability to do any good under the prevailing conditions, but not through any fault of the apparatus. Had the incident consisted solely of the getting out of a number of men under the influence of the gas, the task could have been accomplished with comparative ease. No discomfort was felt by the wearers, who expressed themselves confident of wearing the apparatus for consecutive periods of two hours. The uncanny effect which is usually associated with the use of the mouth-breathing type of apparatus, on account of the wearers having to rely upon signs, was altogether missing upon this occasion, as the officials wore the Dræger helmet, and were thus able to converse freely with each other.

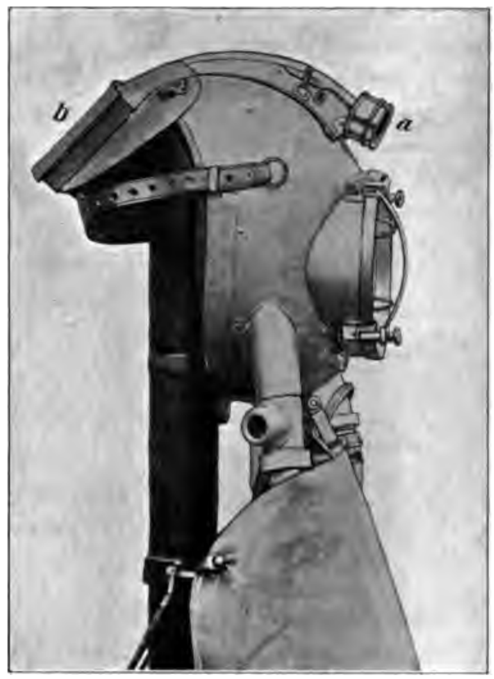

FIG. 2.—DRÆGER HELMET, WITH ELECTRIC LAMP ATTACHED: *a*, LAMP; *b*, ACCUMULATOR.

Another point brought to the writer's notice during this incident was the necessity for a suitable lamp for use in connection with rescue-apparatus. Upon this occasion portable electric lamps were used, and owing to the presence of water the lamp had to be held in one hand and the work done with the other, or the lamp held by a second person, which reduced the working party to half its actual numerical strength. Further, a party is very much handicapped when forcing a passage through a roadway blocked by falls of roof, etc., if only portable hand-lamps are available. The question of the lamp becomes,

therefore, of great importance. The lamp must be considered an indispensible part of the apparatus, and it must be as independent of the prevailing atmospheric conditions as the apparatus itself.

The writer is of opinion that an electric lamp should be attachable to the apparatus in such a position as to involve the least amount of risk of injury, and with its light thrown in the proper direction. A man would then have the free use of both hands, and his rate of progress would thus be increased.

Messrs. Garforth and Dræger have both recognized the importance of this question by attaching an electric lamp to the latest types of their apparatus. That attached to the Dræger helmet is shown in fig. 2. The lamp, *a*, is carried over the forehead and its light thrown immediately ahead of the worker, whilst the accumulator, *b*, is fixed on the back of the helmet. The lamps are of 1½ and 3 candle-power, and will last for 2½ and 5 hours respectively.

This mission, although unsuccessful in its object, did good, in that it instilled in the men concerned a wonderful confidence in this particular type of apparatus; and, so far as the writer is aware, it was the severest and most practical test to which apparatus of a modern type has been put in actual underground work in this country. So much is at stake in the actual use of any form of artificial-breathing apparatus that every little point likely to add to their general utility and the comfort with which they can be worn should receive its full share of consideration.

[redacted]

greatest care would have to be taken to ensure that the apparatus was in proper working order; otherwise, instead of its being an advantage, an element of danger would be thereby introduced. It would be absolutely necessary, he thought, that some maximum time should be stated in the rules beyond which the apparatus should not be allowed to remain at the colliery. This question had been discussed at Wath, where recently a joint rescue-station had been established, and the committee there were agreed that there should be separate sets of apparatus at the pits; but that they should be brought back to the station at short intervals and replaced by other apparatus, and also frequently examined, and be under the charge of a competent person, whilst at the colliery.

Regarding Sergeant Winborn's suggestion that training should not be confined to one kind of apparatus, it had always occurred to him that it would be far better if a rescue-station could be fitted with one kind of apparatus, so that in case of necessity there would be no doubt about having men available who had been trained in the use of the particular kind at the station or sub-station.

Mr. W. H. Chambers (Denaby) wrote that the experience given by Mr. Wroe of the practical use of rescue-apparatus for supplying a pure breathable air, enabling workmen to penetrate an irrespirable atmosphere and to perform most useful service under such extremely trying and dangerous conditions, was of the utmost interest to everyone responsible for the safety of mines. It illustrated the absolute necessity of the provision of such apparatus, with a competent staff to wear it, at every properly equipped colliery, not only for the protection of the mine-workers, but for the sake of the mine itself; whilst the cost incurred should be regarded as a moderate premium of insurance, covering many thousands of pounds involved. The lessons taught had been admirably pointed out by both Mr. Wroe and Sergeant Winborn, and most of the members would concur in the recommendation of those gentlemen that two or three sets of apparatus should be available on the spot, housed in dust-tight receptacles in a cool and dry station, and under the charge of a careful attendant, capable of seeing them properly fitted to persons required to wear them.

Telephonic communication should be available, so that in the event of circumstances arising such as to necessitate the use of the

apparatus, a message might immediately be transmitted to the central station to send on more apparatus in substitution of that in use when exhausted, together with means for replenishing it. It was decidedly an advantage that wearers of such appliances should be thoroughly instructed in ambulance work, with a view to their becoming competent to treat properly unconscious or injured persons reached in the mine, and convey them to a place of safety with the least distress and danger to themselves or their patients.

The pioneer rescue-station in this country, established at Tankersley, was now being followed by others, and it was certain that such stations would be multiplied to serve reasonable areas; but, as yet, those who appreciated the necessity thereof were much exercised as to what type of apparatus to adopt.

It appeared to the writer that a test should be made (1) as to which type of apparatus inexperienced men could most readily be trained to wear with confidence; (2) as to which type was most reliable in use; (3) which would keep most efficient in a charged condition; (4) which was the simplest to clean and recharge; (5) which weighed the least, or had the weight best distributed; (6) which was least bulky, or likely to impede the passage of the wearer through contracted openings, or along low and narrow roads, over falls, etc.; and (7) which was least costly in first charge and upkeep. Perhaps the time had arrived when a committee might, with advantage, be appointed to investigate those and other points.

[redacted]

For dealing with fires, the helmet type of apparatus (which covered all the face and part of the head) might be advantageous, for the reason stated by Mr. Winborn, but he (Mr. Lloyd) would like to point out that the lower part of the arms, which could not be protected whilst engaged in putting out a fire, were as much exposed to the heated atmosphere in the helmet type as in any other apparatus: it was of no use protecting one part of the body and leaving other parts exposed. He also thought that the best apparatus was one which only covered part of the face, allowing the wearer to breathe through both nose and mouth, and leaving the eyes and ears free, with an arrangement by which smoke-goggles could be used, if necessary, to protect the eyes. Experience in underground fires had shown that the eyes could withstand almost as much heat as the hands, and this was proved on the surface in the case of men working at furnaces in glass-works and iron-works. The moisture from the wearer's breath, which collected on the glass or mica pane of the helmet, thereby obscuring the vision of the explorer, was for obvious reasons a serious drawback. With respect to the supply of oxygen playing on the face with a cooling effect, as stated by Mr. Winborn, his experience with the Dræger apparatus was that after a short time this effect was much reduced, and the helmet became uncomfortably hot. It should also be borne in mind that if the glass or mica pane in front of the helmet (and there was a fairly large surface of it exposed) became broken by heat or an accident, then the whole apparatus was immediately rendered useless and the wearer placed in jeopardy.

Mr. M. H. Habershon (Thorncliffe collieries) stated that the suggestions that trained men should be kept on different shifts, and that a station should be in telephonic communication with the pits, were both referred to in his paper communicated to the members some years ago.* Mr. Wroe had, however, made one or two suggestions which he could not endorse. It was very natural that a desire should now be expressed for apparatus to be stationed at collieries, but he thought that it would be chiefly in cases of underground fires that apparatus so placed would be most useful, and in such cases men had probably not far to retreat from the seat of the fire to a place of comparative safety. It was

* "A Joint Colliery Rescue-station," by Mr. M. H. Habershon, *Trans. Inst. M. E.*, 1901, vol. xxi., page 100.

quite a different thing, however, when men had to travel, say, only 100 yards in a noxious atmosphere wherein they knew that life could not be maintained, and he thought that in such cases the presence of the apparatus at the pit might introduce an unnecessary element of danger or risk. In addition to having the apparatus, it was necessary that they should have the trained men to wear it; and they must also have a competent man who was an expert to fit the apparatus on these men and to see that they were properly trained. The members must remember that the manager or undermanager, or some other person in charge for the time being, was responsible; and he would want to know that the men were properly trained, and to be quite certain that the apparatus was properly fitted. They could not do away with the personal responsibility of the certificated manager or the man in charge. It was necessary to prevent the danger of any mishap arising owing to some man putting the apparatus on who was not properly trained, or upon whom the apparatus was not properly fitted, and he thought that it would be better to make haste slowly rather than to endeavour to advance beyond their experience. At the present stage of development of this question, it would, he thought, be better to rely upon the joint rescue-stations rather than run the risks to which he had alluded. In the course of time, perhaps, they might keep adequately trained experts at the collieries, but at the present time they were not there.

The suggestion in Mr. Wroe's paper, that all officials should [redacted]

rescue-station would depend as much on the personal element as on the efficiency of the apparatus."* He thought that here was a point which deserved their attention, for they would find it fruitless to have apparatus installed at collieries unless they had capable men and officials interested in its use. The great danger to be feared with rescue-stations and in this description of work was that, after a long period of absence from any emergency, a false sense of confidence might be established. He was the last person to say anything that would retard in the least the development of this question, but there were so many things to consider that he thought, at present, it must be remembered that when they had provided the apparatus at a colliery they had not done all that was necessary. There was much more to be done before success was attained.

Mr. W. H. Pickering (H.M. Inspector of Mines, Doncaster) said that he desired to join in congratulating Mr. Wroe and Sergeant Winborn upon their papers, which gave a clear account of their experiences. Sergeant Winborn responded most promptly to the sudden call, and Mr. Wroe not only made good use of the apparatus when it arrived, but had previously exerted most intelligent efforts which prevented the fire from obtaining the upper hand in the first instance. He hoped that this proof of the practical utility of the rescue-stations would stimulate interest and lead to the establishment of others.

He agreed with Mr. W. H. Chambers that it was desirable to appoint a sub-committee to inspect the various types of apparatus and to report thereon to the Institute.

The members might be interested to hear that apparatus enabling men to work underground in irrespirable gases was in daily use in Burma. In the Yenangyaung oil-fields on the Irrawady river, the oil was being obtained by deep borings in very large quantities by a company with most up-to-date machinery; but amongst the wells with modern equipment there were scattered wells where work was carried on in the most primitive way by natives. These wells were obtaining petroleum from the oil-bearing strata nearest the surface, and many of them were at work before the British Government annexed the country. With Great Britain's customary equity in dealing with

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 129.

the natives of our dominions, the hereditary rights of the natives to get the oil were respected and confirmed.

These people won the petroleum by sinking square shafts to the sandstones in which the oil occurs. When a shaft neared the sandstone, it became foul with petroleum-gas, which was both explosive and irrespirable, and no one could work without an apparatus to give him fresh air. Many of the Burmese were expert divers, and formerly it was the custom for men to be quickly lowered into the wells where they would work for about two minutes without drawing breath. With the introduction of diving dresses for the pearl divers of the Mergui Archipelago, off the Burmese coast, the hint was given to the ingenious miners that these dresses might be used for their work. They adopted them in their entirety, lead-weighted boots and other heavy fittings, but eventually an improved apparatus was designed. It consisted of a tin helmet, with glazed outlook-holes, fitting very loosely over the head. A tube was attached to the helmet with the delivery-end just over the nose of the wearer. Air was forced down the tube by a diver's air-pump. A coarse cotton jacket was attached to the helmet and was tied round the waist. The fresh air passed over the nose and mouth of the worker, who breathed naturally. The air inflated the jacket and escaped through the pores of the fabric. The apparatus was exceedingly light, and scarcely impeded the worker at all, and a man would work for two hours without discomfort. He (Mr. Pickering) had [redacted]

Mr. A. H. Barnard (Denaby) asked why it was that such stress was laid upon conducting practices at a rescue-station in vitiated atmospheres. He did not quite see what difference it made to the man wearing the apparatus, as he was isolated from the atmosphere.

Mr. M. H. Habershon, referring to the question of keeping the apparatus at the pits, remarked that practice in an experimental gallery from which exit was easy was very different from actual work underground under conditions of real danger. In the incident recorded by Sergeant Winborn, one of the men employed was not so well trained as the others, and that had been discovered. What he feared was that in a moment of excitement the apparatus might be worn by men who were not properly trained, or who might have it fitted on inefficiently. The time would come when they would have apparatus at the pits, but for the moment he would rather trust in the rescue-stations. The organization at the Tankersley rescue-station was inadequate, yet it had been sufficient to provide apparatus, and to ensure its successful use, having been the means of saving valuable property.

Mr. John Gerrard (H.M. Inspector of Mines, Worsley) said that the two papers had come at the right time when people were asking what was the use of rescue-stations, and what was the use of rescue-apparatus. In the initiatory stage it was necessary that they should move with great caution, and that was the view which he thought Mr. Habershon had put prominently before them. For instance, they knew what use was made of rescue-apparatus at Courrières, and how the experience gained there had been used over and over again as an argument against rescue-apparatus. True, a man wearing rescue-apparatus had actually lost his life at Courrières. Very few knew the facts, or how that loss of life occurred; and that if care had been taken, the man would not have been allowed to go into the mine with the apparatus on. There was a similar experience at Felling-upon-Tyne in August, 1907, when an exhibition-demonstration of rescue-apparatus was held. At the last moment, a man, who ought not to have been permitted to wear the apparatus, he having had no previous experience of it, was allowed to compete with the wearers of other apparatus, and it was only owing to

the vigilance of the late Mr. M. Walton Brown that the man was discovered to be in difficulties. Mr. Brown called the attention of a doctor to the man, and had him brought out of the experimental gallery. This doctor was not impressed with the importance of the situation, and would have permitted the man to continue; but Mr. Brown called in a second doctor, who, after examining the man carefully, ordered him to stop at once and to go to bed. In a very short time the man was almost unconscious. It was to prevent such occurrences as these that Mr. Habershon spoke so cautiously. If individual collieries would undertake to bestow requisite care upon the apparatus and to keep them as they ought to be kept, ready for instant use; and if they would train a staff of men, and see that they were constantly practising, then such collieries would be on a par with the rescue-station; but how were they going to ensure this? At the present stage, much was to be said for Mr. Habershon's view, and he thought that they had better bear with the present arrangement, even if it took them three-quarters of an hour to reach the colliery, and thereby have an apparatus which could be depended upon not to lose life, and men who had experience to wear it. Let them not fight over details, but rather press forward the establishment of the best rescue-station and the best apparatus, extending their knowledge by the experience thus gained.

With regard to the form which the apparatus should take, the fight that was now going on in France on this subject reminded [redacted]

person permitted to use such apparatus should first be the holder of a certificate of efficiency granted by the officials at the rescue-station.

Sergeant WINBORN (Tankersley) said that practice in an irrespirable atmosphere was of the utmost importance. In the training of any number of men, there was likely to exist a certain amount of rivalry as to the period during which they were able to wear an apparatus, and as to the amount of work that they were able to perform, and one could not always trust to a man's sincerity in correctly wearing the apparatus. It was possible for a man wearing an apparatus to arrange it so that he was not breathing the air from the apparatus alone, but that of the outer atmosphere also. They must guard against that, and be sure that the man was wearing his apparatus correctly. Further, a man would never gain sufficient confidence in his apparatus by wearing it under ordinary atmospheric conditions. It would merely be so much waste of oxygen, etc. Practising in a noxious atmosphere gave a man confidence both in himself and in his apparatus, and this was what was wanted.

Mr. Lloyd seemed to imply that anyone wearing the Dræger helmet could not hear what was going on around him. This was certainly not the case. The ears were not encased in the helmet, but were outside it. A great advantage of the helmet, in addition to natural respiration, was the fact that men wearing it could converse freely. Concerning Mr. Lloyd's remarks that it was of no use protecting part of one's person while exposing the other (namely, protecting the face and head and not the arms and legs), he (Sergeant Winborn) considered the protection of the face to be of more vital importance than the protection of other parts of the person. For instance, one would not be seriously incapacitated by a burn upon the hands or legs, but the same injury to the face might bring about an immediate retirement. In the case of the fire at Wharncliffe Silkstone collieries, Mr. Wroe had pointed out that the wearers of the apparatus received a few slight burns upon the hands. This, however, did not interfere with their work in quelling the fire; in fact, the burns were not noticed until after the task was accomplished, and the fire subdued. Quite a different tale might have been told, had those burns been received

upon the face. It was not a difficult matter to protect the face from injury from flames, but it would render an apparatus exceedingly cumbrous to afford similar protection to one's whole person. A certain amount of moisture from the wearer's breath did collect upon the mica pane of the helmet, but this was no serious drawback, as the moisture could be easily removed by means of a sponge fixed inside the helmet, although manipulated from the outside. This appliance could also be used for the purpose of sponging one's eyes and face. The mica pane was protected by a wire-guard. It must be remembered that the Drægar apparatus did not consist solely of the helmet form, but was so arranged that it could be used in connection with a helmet or with a mouth-breathing bag, either of which could be used, as desired, without any alteration to the actual apparatus. The Westphalia Shamrock type of apparatus also possessed this advantage.

The further discussion of the two papers was adjourned.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT THE STORK HOTEL, WALSALL, FEBRUARY 5TH, 1908.

MR. ALEXANDER SMITH, PRESIDENT, IN THE CHAIR.

The minutes of the last General and of Council Meetings were read and confirmed.

Prof. LEONARD HILL read the following paper on "Breathing-apparatus for Use in Mines":—

BREATHING-APPARATUS FOR USE IN MINES.

By PROF. LEONARD HILL.

SECTION I.—SOME CONSIDERATIONS ON THE PHYSIOLOGICAL EFFECTS OF FOUL AIR, AND THE PRINCIPLES OF CONSTRUCTION OF BREATHING-APPARATUS.

Oxygen.—The air of mines may be vitiated and rendered dangerous to man in a variety of ways. Processes of oxidation are constantly going on in the soil, which result in the impoverishment of the oxygen of the air in wells and mines and the formation of carbonic acid. Iron pyrites (FeS_2) is decomposed by moist air, sulphate of iron ($FeSO_4$) is formed, and sulphur is oxidized into sulphurous anhydride (SO_2). The sulphurous anhydride combines with water to form sulphurous acid (H_2SO_3), and this in its turn oxidizes to sulphuric acid (H_2SO_4). The sulphuric acid, thus formed, coming into contact with carbonate of lime in the soil, evolves carbonic acid (CO_2). Air impoverished by such oxidizing processes becomes insufficient to support combustion, when the oxygen-tension falls from the normal 21 to 17·3 per cent. of an atmosphere. The presence of such impover-[redacted]

the wellknown pale cap-flame to the miners' lamps when present to the extent of more than 2 per cent., and is explosive in percentages above 6. It has no poisonous action on man, except in so far as it dilutes the oxygen of the air.

Influence of De-oxygenated Air on Man.—When the oxygen is reduced to 15 per cent. (that is, less than sufficient to support a flame), slight dizziness and shortness of breath may occur on exertion. When the tension of oxygen falls to 10 per cent., the respirations of a man who is resting become deeper and more frequent, the pulse more frequent, and the colour of the face dusky; and when the tension falls to 7 per cent. the mind becomes confused, the muscular power impaired, the face leaden in colour, the heart palpitates, and the respiration becomes panting. At slightly lower tensions than this, consciousness is lost and life is in imminent danger. The discomfort felt by the person exposed to gradually decreasing tensions of oxygen is often slight, and gives little or no warning of danger; and herein lies the great risk of going into de-oxygenated air without a breathing-apparatus, and the necessity of ensuring that the oxygen-supply to the breathing-bag of such an apparatus should not fail unknown to the wearer. It is absolutely essential that the gauge of the oxygen-supply be placed in a position visible to the wearer.

Influence of Excess of Oxygen on Man.—Breathing an excess of oxygen up to one atmosphere of pure oxygen has no effect on the rate of the oxidizing processes of the human body. Such an excess (50 to 70 per cent. in the Fleuss-Siebe Gorman breathing-bag) can be breathed in perfect safety for many hours. It is not, however, safe to breathe oxygen at tensions above one atmosphere for long periods, because oxygen in high concentration produces: (1) inflammation of the lungs, and (2) poisoning of the nervous system and convulsions. Exposure to three atmospheres of pure oxygen very rapidly causes convulsions in animals.

Carbonic Acid and its Influence on Man.—Pure air contains 0·03 per cent. of carbonic acid. The air in crowded halls may contain as much as 0·5 per cent. An excess of this gas causes no noticeable effects, until the proportion rises to about 3 per cent.

This amount causes deeper and more frequent respirations, while the pulse becomes fuller and more frequent. Four per cent. produces unpleasant panting, and greatly diminishes the power to do work. At 6 to 7 per cent., there is marked and distressful panting, and at 10 per cent. violent panting, throbbing of the arteries, and flushing of the face. Pressures above 25 per cent. of carbonic acid may cause death in animals, but only after exposure to it for several hours. The popular idea that a small increase in carbonic-acid pressure is deleterious has no foundation in fact. Probably no cases of poisoning from carbonic acid ever occur, for choke-damp which contains any large percentage kills by want of oxygen, not by excess of carbonic acid. As a matter of comfort, it is needful to keep the carbonic acid in a breathing-apparatus under 3 per cent. and it is best to aim at keeping it under 1 per cent., because some men may suffer from headache after a prolonged exposure to as much as 3 per cent., and this amount reduces the power to do work. On holding the breath as long as possible, as in diving under water, the air in the lungs is found to contain about 10 to 12 per cent. of oxygen and 7 to 10 per cent. of carbonic acid. Normally there is about 5 per cent. of carbonic acid in the air within the lungs. It is clear, then, that a temporary rise of 3 per cent. in the carbonic-acid tension in the lungs is quite a natural phenomenon. Carbonic acid is used by hygienists as the indicator of efficient ventilation of rooms, not because it is poisonous,

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the intake roads where there is not even a trace of fire-damp, but where there is much dry and very fine dust. As there is more dust in the air than can be completely burnt by the oxygen, carbonic oxide is formed. In many parts, however, there is probably so much dust that ignition cannot occur at all, so that the "after-damp contains plenty of oxygen."* Thus the bodies of those found in the track of the explosion show that they have died gradually from carbon-monoxide poisoning, and not suddenly from asphyxia. Men, as is well known, may survive in the pockets of pure air, as was the case at the Courrières disaster. The breathing-apparatus is required to rescue these.

Carbon monoxide combines chemically with the hæmoglobin of the blood, and destroys life by robbing the body of oxygen, which is normally carried by the hæmoglobin. The gas is not a poison, except in so far as it is an oxygen-robber. This is proved by the fact that animals poisoned with the gas can be kept alive and vigorous in two atmospheres of pure oxygen, for then oxygen is dissolved in the blood-plasma sufficiently to maintain life independently of the oxygen-carrying function of the hæmoglobin. If blood be shaken with air containing 0·07 per cent. of carbon monoxide and 21 per cent. of oxygen, the hæmoglobin is found to be shared equally between the two gases. Thus, carbon monoxide has an affinity for hæmoglobin 300 times greater than that of oxygen.

When the blood is saturated with 20 per cent. of carbon monoxide, there occurs dizziness and shortness of breath on exertion. The symptoms are aggravated by increasing saturation in a very insidious and dangerous manner, there being little sense of discomfort to warn the subject of the increasing failure of his mental and physical powers. "At 50 per cent. saturation, it is scarcely possible to stand, and the slightest exertion causes temporary loss of consciousness."† Exertion by using up the oxygen in the muscles hastens the failure of the heart's action; there may result degenerative changes in, and lasting weakness of, the heart in those rescued from death. It is important to remember that exposure of the sufferer to cold fresh air aggra-

* "Effects of Atmosphere," by Dr. J. S. Haldane, *Text-book of Pharmacology and Therapeutics*, page 56.

† *The Investigation of Mine Air*, by Sir C. Le Neve Foster and Dr. J. S. Haldane, page 146.

vates the symptoms, and may be fatal. The heart requires all the available oxygen, and to that end the body must be kept warm by external heat, so that no demand is made on the heat-producing (oxidizing) mechanism of the body. The tube from an oxygen-cylinder should be allowed to play into the sufferer's mouth for at least a quarter of an hour, and artificial respiration given if necessary. If the breathing be re-established properly, all danger from the carbon monoxide in the blood is over at the end of an hour.* Prolonged nursing may be required to steer the patient through the subsequent fatty degenerations of the tissues which may result.

Anything above 0·15 per cent. of carbon monoxide in the air breathed is dangerous; 0·4 per cent. will practically always cause death. Mice are affected much sooner than a man is, and should be carried by rescue-parties and used as an index of the state of the air.

Ordinary coal-gas contains 5 to 12 per cent. of carbon monoxide, and carburetted water-gas 30 to 40 per cent. Carbon monoxide is a product of imperfect combustion, as in the smouldering fires of mine-timbers, and is also present in the gas formed in the explosion of gunpowder and gun-cotton. Owing to the insidiously poisonous nature of after-damp, it is foolhardy and suicidal for the bravest rescue-party to try and face it without breathing-apparatus. It is especially to meet the peril of after-damp that such apparatus is required, in order [redacted]

The Royal Commission on Mines and the Need of Breathing-apparatus.—The Royal Commission on Mines says:*—

"Apart from actual rescue-work, breathing-appliances may be of great service in making it possible to deal with underground fires more safely and effectively than would otherwise be the case. In the event of a gob-fire, for instance, the seat of the fire may, on account of smoke, be inaccessible without great risk, and in such a case breathing-appliances could obviously be used with much advantage in exploring and directly attacking the seat of the fire, in building stoppings close up to it, and in preventing the poisonous fumes from menacing the safety of men beyond. . . . . In the report already mentioned on a recent visit to the Westphalian coal-field it is pointed out that 'the pecuniary advantages resulting from the use of apparatus for penetrating irrespirable atmospheres and water has had quite as much to do with their general adoption in Westphalian mines as the desire to have the means at command for saving life.' . . . . Some British collieries are seldom free from gob-fires or dangerous heating; these fires often cause not only danger to life but great loss of property to coal-owners, and loss of employment to men. Hence, there seems to be a considerable field for the use of breathing-appliances, apart altogether from rescue-work after explosions."*

Breathing-apparatus.—The objects of such apparatus are:—(1) To allow the wearer to remain in an irrespirable or poisonous atmosphere for a given period of time; (2) to do efficient work; and (3) to crawl through or under obstacles (such as occur after a mine-explosion) as much as possible with the same ease and safety as an unencumbered man.

These objects are attained by connecting the mouth with a breathing-bag or box, into which oxygen is delivered, and from which the exhaled carbonic acid is absorbed; by making and arranging the required apparatus so that it is as light as possible; by adapting it to the body in such a way as to unfetter the movements of the wearer while increasing the girth of the body as little as possible. The apparatus, too, must not project in such a way as to dislodge beams, rocks, etc., when the wearer is exploring dangerously-encumbered ways after an explosion. The apparatus should fit him so that he knows that he can pass through where his head and shoulders can pass. The apparatus must be air-tight from without inwards, to prevent the entrance of irritating vapours such as thick smoke, and the eyes must be protected from the same. In the case of after-damp, the latter protection is not required. It is of great value that the apparatus should allow of the mouthpiece being removed so that a few words of direction may be spoken or drink taken if

* *First Report of the Royal Commission on Mines*, 1907 [Cd. 3548], page 10.

occasion arises. There is no risk in doing this, so long as the tube leading from the mouthpiece to the breathing-bag can be closed by the thumb.

Breathing-space.—The breathing-bag must be large enough to contain the deepest inspiration or expiration quite easily. Inspiration out of an empty, or expiration into a full, bag is very distressing and not free from risk. The breathing volume while resting is about 30½ cubic inches (500 cubic centimetres); while working it may reach 91½ cubic inches (1,500 cubic centimetres). The bag must be moderately distensible, so as to act as a buffer or cushion for the ebb and flow or inspiration and expiration.

The Oxygen-supply.—A man at rest requires on the average about 15 cubic inches (250 cubic centimetres) of oxygen per minute, and at work climbing hills from 73 to 91 cubic inches (1,200 to 1,500 cubic centimetres) per minute. The use may rise to 122 cubic inches (2,000 cubic centimetres, or 2 litres) per minute. This amount, therefore, must be continuously supplied so that shortage can in no case occur, for it is very dangerous if the oxygen-tension falls to less than 12 per cent. The breathing-bag should be washed out with oxygen when the wearer puts on the apparatus, so that it contains 60 to 70 per cent. of oxygen. Diminution in the volume of the breathing-bag will then warn the wearer, by making inspiration difficult before the oxygen-tension gets to a dangerously low level.

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Simplicity, Strength, and Lightness.—It is most desirable that the apparatus should be constructed as simply and strongly as possible, so that it cannot get out of order when hung up in store, and can be understood by any ordinary workman, and safely worn by him after no more than a few minutes' training. The apparatus, moreover, should be so designed that the man who is to wear it can put it on himself, without assistance, in the shortest possible time, and it should also be as light as possible.

SECTION II.—THE IMPROVED FLEUSS-SIEBE GORMAN APPARATUS.

The Fleuss-Siebe Gorman dress of to-day is the perfected form of the apparatus which Mr. Fleuss exhibited in 1880 to the South Wales Institute of Engineers,* and with which, in a form modified for use under water, he saved the Severn Tunnel from flooding, as noted in the following paragraph:—†

"On arriving at the tunnel works with his diving apparatus, he went down the shaft, and some distance along the subway, but as he had never been underground before, and everything was strange to him, he could not penetrate as far as the door [which had been left open by the men when the spring was struck]; and on returning to the surface he said he would go down again if they would allow him to make a second attempt. The diver [Lambert], however, then offered to go down in his dress and apparatus, and after explaining to him the mode of using it, he did so. The diver had to cross over two trams which had been left on the road, remove some metals which were jammed in the door, close two sluices, and shut the door, all of which he successfully accomplished in about one-hour-and-a-half. The depth of the shaft was about 210 feet, in which there was about 39 feet of water when he descended, and he had to travel the distance of 1,200 feet along the submerged subway from the bottom of the shaft, and back again."

Subsequently to this the original Fleuss apparatus was used "for conducting some of the most dangerous of the exploration-work at Seaham colliery, after the fire which succeeded the unfortunate explosion which took place at that colliery in 1881."‡

Mr. Hedley, in his paper, says:—

"The novelty of the apparatus, and the principles on which it depended, which at first sight would seem obscure to any but a chemist or physiologist, might lead to the supposition that there would arise some difficulty in its ready use by

* "On Diving and Diving Machines, with a Description of Fleuss' Improved Diving and Breathing Apparatus," etc., by Mr. Hort. Huxham, *Trans. S. Wales Inst.*, 1880, vol. xii., page 100.

† *Ibid.*, page 330.

‡ "A Brief Description of the Use of Fleuss's Breathing-apparatus, in Explorations made after the Explosion, at Seaham Colliery," by Mr. Sept. H. Hedley, *ibid.*, 1880, vol. xii., pages 575 and 576.

uneducated or unskilled hands, but the result shows that these fears were groundless, and that there was no practical difficulty in its application." *

"The men were enabled, by using the breather and [Fleuss] lamp, to penetrate into the workings, which were filled with gas [fire-damp] to a considerable distance —in one instance, upwards of 300 yards in advance of the bratticed air—and were able to report as to the state of roof, road, etc." †

Mr. Hedley used the apparatus himself, and found a mouthpiece and goggles much more convenient and comfortable to wear than the mask; the mask, he says, became painful after a short time, owing to the pressure of the bands on his head.

These examples showed how the Fleuss apparatus of twenty-five years ago could be used effectively and safely, even after the briefest training.

The apparatus now exhibited has been so perfected as to satisfy the requirements established by exact physiological investigation, and to give the greatest simplicity and strength with maximum comfort and safety.

The Equipment and Speed of Dressing.—The apparatus is carried in a strong leathern and canvas equipment, so arranged as to distribute the weight equally and comfortably, and, at the same time, to give the wearer free movement of his arms. In the latest design the whole of this equipment is in one piece, consisting of a back-piece to carry the oxygen-cylinders, and a breast-piece to carry the breathing-bag and gauge; the back and breast-pieces are connected by shoulder-straps, leaving a hole for the head. This equipment rests in readiness on a saddle,

[redacted]

Avoidance of Projections.—The back behind the shoulders is quite free, enabling a man to get along in a low mine-road without the least danger of displacing unstable timber or rock. The wearer can crawl through a space measuring 17 inches in width by 15 inches in height. The wearer knows that if his head and shoulders can pass in the crawling posture, the rest of his body, including the oxygen-cylinders, may follow safely.

It is most essential that the danger of the wearer displacing half-fallen *débris* by projecting apparatus should be avoided, and it is equally essential that he should be able to creep through the minimum of space. Nevertheless, in all other forms of apparatus the most bulky parts are placed on the back of the shoulders, and the wearer can have no knowledge of the proximity of these to the dangerous unstable structures which may surround him when exploring a seam after an explosion. The Fleuss-Siebe Gorman apparatus is arranged so that the head and shoulders can act like the vibrissæ of a cat's whiskers, which tell it whether it can pass through a hole or not.

The apparatus is made with the fewest possible connections, and these are all controlled by one spanner. Thus any man can learn to put it together in a few minutes, and there is no danger of any of the parts being misplaced or broken.

Valves of Oxygen-supply.—The oxygen-cylinders are controlled by valves which do not allow the cylinders to leak when not in use. A reducing-valve has been added, delivering approximately 122 cubic inches (2 litres) of oxygen per minute at all pressures. This means a slightly wasteful use of oxygen when the wearer is not working; but waste is deliberately chosen in preference to the risk of deficient oxygen. The Royal Commission on Mines have reported strongly in this sense.* A relief-valve is placed on the breathing-bag, so that the wearer can let out the excess in case the bag becomes over-filled and expiration is thus impeded. In spite of the necessary waste, the oxygen cylinders contain a supply sufficient for two to two-and-a-half hours, according to the size of the cylinders. A bye-pass fitted with an emergency-valve is added, so that the wearer can fill the bag at once on first putting on the dress, or obtain an immediate supply if at any time his bag accidentally is compressed (and the

* *First Report of the Royal Commission on Mines*, 1907 [Cd. 3548], page 42.

gas driven out of it round the mouthpiece), or if the reducing-valve fails to act.

An experienced wearer could safely set the reducing-valve at 61 cubic inches (1 litre) per minute, and obtain a larger supply when needed during great exertion by means of the emergency-tap. By this means he could extend the available time of the oxygen-supply to about three hours. For general use, it is wiser to diminish the available time, in order to gain absolute security from de-oxygenated air. Analyses taken when the Fleuss-Siebe Gorman apparatus is in use show that there is 50 to 80 per cent. of oxygen in the breathing-bag.

Capacity of the Breathing-bag.—The breathing-bag is of ample capacity to yield a sufficient volume of air during the deep respirations of hard labour. It also acts as an efficiently elastic cushion to render the respiration easy and comfortable.

The Absorption of Carbonic Acid.—The caustic soda is placed within the breathing-bag in the form of sticks. The bag can be opened and the sticks dropped in with the greatest ease and quickness; and the vulcanized india-rubber bag can be washed clean of the used soda under a water-tap with no less convenience. There are exhaling and inhaling divisions in the bag, to ensure the passage of the expired air through the soda. With each movement of the wearer, the breathing-bag is jolted, and the carbonized surface is rubbed off the soda. A fresh [redacted]

discomfort produced by breathing carbonic acid up to 3 per cent., and the advantage of carrying the caustic soda in this simple manner outweighs any risk of slight and temporary increase in depth of respiration; this is the only result from breathing 2 to 2·5 per cent. of carbonic acid. To overweight the apparatus or render it clumsy, in order to obtain very low percentages of carbonic acid, is, in regard to breathing-apparatus, a most mistaken policy.

The Gauge Visible to the Wearer.—The pressure-gauge is attached by means of a strong flexible tube to the front of the breathing-bag, so that the wearer can tell at any time what oxygen-supply he has left and beat a retreat at the right moment. This is an absolutely essential improvement, one on which the life of the wearer depends, but one that exists in no other apparatus.

The Mouthpiece and Nose-clip.—The mouthpiece allows the wearer free motion of his head, being connected to the breathing-bag by strong flexible corrugated tubes. The inhaling and exhaling valves in the latest pattern are of mica, and, being of the simplest design, do not stick or get out of order. The dead space between the mouth and the inlet to the bag is not greater than 3 cubic inches (50 cubic centimetres).

The mouthpiece is attached by a small rubber-band, which fits comfortably round the outside of the mouth and buckles behind the head. The band prevents the mouthpiece from being jerked out. The rubber parts of the mouthpiece which come in contact with the gums are soft and comfortable. The mouthpiece can easily be slipped out and the orifice closed by the thumb, while the wearer can say a few words of direction or drink from a flask. This is a point of no little importance.

The nose-clip is made to fit comfortably any nose, and cannot slip off. Mica goggles are supplied to protect the eyes during work in smoke. In place of the mouthpiece, nose-clip, and goggles, a half-mask can be worn if preferred.

The report of the Royal Commission on Mines summarizes the data obtained as to the four points (1) removal of carbonic acid, (2) supply of oxygen, (3) air-tightness, and (4) comfort and convenience, and gives the mark "good" in all four to two forms of apparatus only, namely, the Fleuss-Siebe Gorman, and the Weg.* The report, however, points out that, in the case of the

* *First Report of the Royal Commission on Mines*, 1907 [Cd. 3548], page 42.

Weg dress there is danger in the method by which the oxygen-supply is delivered. This is shown by the analyses given on page 39 of the report, wherein the oxygen in the breathing-bag is shown to have fallen after exertion below the danger limit, namely, to 10·6 per cent. The report says that this danger can be obviated if "the subject draws on the supply in the cylinders in slight excess of his actual requirements and so washes out the apparatus during the whole period of use and wastes some of the oxygen,"* and the conclusion reached is that the constant arrangement of an excess-supply, as in the Fleuss-Siebe Gorman, is preferable. Such a supply relieves the strain of attention on the part of the wearer, relieves him of anxiety, and sets him free to attend to his work. The Weg apparatus is "made only with a mask, and the construction of this, and its connections with the purifier and breathing-bag by means of rigid tubes, necessitate the head-piece of each apparatus being made to fit only one individual."† This seems to be a distinct disadvantage. The Fleuss-Siebe Gorman dress can be made to fit any man by adjusting the length of the straps. Its weight, fully charged, is only 30 pounds, or less than the equipment of a soldier in full marching order; whilst that of the Dræger is 39 pounds, and that of the Weg 38 pounds.

APPENDIX.—REPORT BY PROF. LEONARD HILL ON THE NEW MODEL OF THE FLEUSS-SIEBE GORMAN DRESS, JANUARY 10TH, 1908.

			Analysis of Inspired Air.

[redacted]

The PRESIDENT (Mr. Alexander Smith, Birmingham) complimented Prof. Hill upon his able paper. That gentleman had put before them the physiological effects of foul air and the principles governing the construction of the improved Fleuss-Gorman breathing-apparatus, and had demonstrated the greatly superior design of the present type over the old Fleuss apparatus. Their past experience with regard to life-saving appliances had been that when the time for using them arrived, the apparatus was found to have been stowed away in the stores and forgotten, and when required it was discovered to be out of order. To guard against this, efforts were now being made for the establishment of properly trained corps, similar to those for ambulance or fire purposes, with stations favourably situated ready for all emergencies.

Mr. WILLIAM CHARLTON (Walsall) said that the members of the Institute were much indebted to Prof. Hill for his lucid paper, and for the demonstration with one type of self-contained breathing-apparatus. A great deal had recently been written on the subject, and the publicity which it received consequent on the work of the Westphalian rescue-corps at the Courrières collieries had directed to the subject an enormous amount of interest. It was possible that this suddenly-awakened interest might acquire such momentum as to lead to the adoption of the apparatus under circumstances where it might not only be of no use, but, in the absence of proper training and efficient supervision in maintenance, might be a positive danger. It no doubt came within the scope of their own and other mining institutes to consider the subject carefully, and, after taking into account the conditions of local mining, to advise the adoption or otherwise at local collieries, of self-contained breathing-apparatus; and, further, to consider schemes for the mutual support of central stations for the storage of such apparatus and the drilling of men volunteering for the purpose. It would be well, however, to bear in mind that, as considerable cost would be incurred, the ultimate decision in the matter must rest with the coal-owners.

Prof. Hill had brought before the members one example of a type of self-contained breathing-apparatus, namely, the regenerator type. This type of apparatus might be divided into two classes. It had been ascertained that the maximum quantity

of oxygen consumed by an adult when performing hard work was 122 cubic inches (2 litres) per minute, and one class of this type supplied this maximum quantity during the whole time that the apparatus was in use. In the second type, represented by the Weg, the supply of oxygen was variable, and was governed by the rate of inspiration of the wearer. In the first-named type there was a relief-valve, in the event of the breathing-bag becoming unduly inflated when the wearer was at rest and not consuming the maximum quantity of oxygen supplied by the oxygen-cylinders. No such device was necessary in the Weg apparatus. Some interesting particulars of tests made with the Dræger and Weg apparatus at Messrs. Pope and Pearson's collieries at Altofts, in an experimental gallery filled with an irrespirable atmosphere, and with four men wearing the Dræger and four wearing the Weg apparatus, had appeared in the *Transactions.**

Another type of apparatus was the Pneumatogen, which differed entirely from the former type.† The oxygen required was not carried in a compressed form in cylinders, but was generated as required by the action of carbonic acid and water in the expired air upon the peroxides of potassium and sodium.

Dr. A. E. Boycott, referring to the Pneumatogen, in his report to the Royal Commission on Mines, stated that—

"Within comparatively narrow limits of variation the amount of oxygen required is proportional to the quantity of carbon-dioxide and water exhaled; as the peroxide yields oxygen in proportion to the carbon-dioxide and water acting [redacted]

"The apparatus seems to be admirably adapted for the purpose for which it was designed, *i.e.*, to enable workmen to escape from the face through a dangerous atmosphere to the shaft." *

A third type of apparatus was the Aerolith, which used liquid air, and which had been fully described in the *Transactions*.†

Dr. Boycott, referring to the Aerolith, in his report to the Royal Commission on Mines, said:—

"It is supposed that the amount [of air] evaporated from the box depends upon the quantity of hot expired air which passes along the expiratory tube, and therefore upon the degree of exertion, and that in this way the supply of air varies with the requirements of the user."

"Measurements were made of the quantity of air leaving the apparatus in successive minutes, in the absence of respiration, and during periods of violent breathing in and out of the bag through the box. The results indicated that the degree of respiration would have practically no influence on the amount of air evaporated. They also show that the discharge is not regular, being excessive at first and in defect towards the end." ‡

This opinion was somewhat corrected by the fact that the nitrogen evaporated from liquid air more rapidly than oxygen; hence, towards the end, the apparatus contained more oxygen relatively than at the beginning. Dr. Boycott had formulated certain objections to the liquid-air apparatus submitted to the Royal Commission on Mines, namely:—

"The time during which the apparatus can be used is indicated only by the quantity of liquid air put in. This is determined by weighing the apparatus on a spring balance. . . . . There is, therefore, no means of warning the user when the supply is coming to an end, or, which is perhaps more important, of ascertaining when it is half exhausted."

"The second objection is found in the difficulty of keeping a supply of liquid air constantly at hand. At present in this country the available sources of supply are limited, and, unless liquid air comes into more extensive commercial use, this must always restrict the use of the apparatus." §

In summarizing the investigations of the Royal Commission, Dr. Boycott ruled out apparatus of the Pneumatogen and liquid-air types for rescue-work, where severe muscular exertion had to be performed; and, so far as could be seen at present, attention must be confined to the apparatus of the regenerator type, either

* *First Report of the Royal Commission on Mines*, 1907 [Cd. 3548], page 22.

† "Liquid Air and its Use in Rescue-apparatus," by Mr. Otto Simonis, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 534.

‡ *First Report of the Royal Commission on Mines*, 1907 [Cd. 3548], page 40.

§ *Ibid.*, page 41.

for rescue-work after an explosion, or for dealing with underground fires. Dr. Boycott gave the following essential data with regard to the various types of rescue-apparatus:—*

Apparatus.	Weight in Pounds.	Oxygen Capacity.		Removal of Carbonic Acid.	Supply of Oxygen.	Air-tightness.	Comfort and Convenience.
		Cub. Ft.	Litres.				
Pneumatogen (Type II.)	14½	5·8	163*	Good	Poor	Good	Very good
Dræger	36-39	8·9	251	,,	Good	,,	Bad
Shamrock	36	9·7	274	Bad	,,	,,	Good
Fleuss	31	8·0	228	Good	,,	,,	,,
Weg	about 30	5·3	150	,,	,,	,,	,,
Aerolith	22	?	?	Fair	,,	,,	Very good

* Maximum theoretical yield; 80 to 100 litres is the more probable figure in actual practice.

Judging from all the evidence now available, it might be fairly well concluded that, given sufficient care in its maintenance, the regenerator type of self-contained breathing-apparatus was practicable for the performance of work, for a limited period, in irrespirable atmospheres. For the carrying out of that work, however, with the greatest possible safety, there were a few points which required attention, namely:—(1) The maintenance of the apparatus in an efficient condition. This subject had been elaborately treated in a contribution to the *Transactions* by Mr. M. H. Habershon.† (2) The men who volunteered to use the apparatus in case of accident should be carefully and systematically trained in its use, and under conditions as nearly similar to those of the mine as could be reproduced in an experimental [redacted]

stored, in charge of a qualified caretaker, who would be responsible for maintaining the apparatus in an efficient condition, and be able at a moment's notice to certify a certain proportion of the sets in his charge as immediately available for use. The suggestion went further, as it was proposed that a certain number of men from each colliery should be regularly instructed and trained in the use of the apparatus at the central station; such station to be in telephonic communication with each colliery, and provided with a means of conveyance at call.

An alternative or variation which had been adopted by the Fife and Clackmannan Coal-owners' Association was the establishment of central stations on co-operative lines;* but, in addition, each colliery was to be provided with not less than five sets of apparatus on its own premises. It appeared to the writer that the first-named plan was most conducive to the apparatus being maintained in an efficient condition, and it probably could be taken to a colliery as quickly as the men to wear it could be summoned and arrive there.

Local conditions must enter largely into the desirability and extent to which rescue-apparatus should be provided. So far as the writer knew the history of the district covered by the Institute, there was no record of any large colliery-explosion, or any explosion where the use of self-contained breathing-apparatus would have been of the slightest use.

The Royal Commission on Mines had suggested that the apparatus might be useful in dealing with underground fires.† At this point, the subject became of real interest to the Midland district, as underground fires, incipient or active, were a common experience. The use of apparatus might, it appeared to the writer, reduce the inconveniences sometimes experienced in loading out heated material, or sealing off, or opening fire-dams; but for dealing with active fires, the rubber of the apparatus was likely to suffer damage, and possibly destroy its efficacy. This possible use of the apparatus did not appear to demand anything like the provision of stations and appliances that the liabilities to explosion on a large scale might make advisable.

* "Rescue-apparatus for Use in Mines," by Mr. James Bain, *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 72.

† *First Report of the Royal Commission on Mines*, 1907 [Cd. 3548], page 10.

In conclusion, the writer pointed out that if any scheme or plan for the establishment of rescue-stations or apparatus was considered, the possible future charges should be reasonably anticipated in order that the plan or scheme might be persevered with. The following points were worthy of consideration:—

(1) In providing apparatus, no sense of finality should be harboured, but provision made to adopt improvements or new apparatus.

(2) An extended lesson for four men might involve an expenditure of about £3.

(3) The cost of a caretaker responsible for the efficient maintenance of apparatus.

(4) Payments to men for time spent in training.

These were mentioned as constantly recurring charges, in addition to the first or capital expenditure on buildings and apparatus. It appeared that the South Wales coal-owners were spending £2,000 on each of their rescue-stations and making a provision of £500 per year for the maintenance of each station.

Mr. S. F. Sopwith (Cannock Chase) wished to ask how long the proper pressure of the oxygen-gas in the cylinders could be maintained when the apparatus was not in use: that was, whether there was any leakage of the taps.

Mr. T. J. Davies (West Bromwich) said that he had had very little experience of rescue-apparatus, but he thought that an im- [redacted]

spoken by Mr. Charlton as to forming too hasty an opinion or an exaggerated estimate of the utility of such appliances.

A question was asked in the House of Commons on the occasion of a recent explosion in South Wales, calling the Home Secretary's attention to the absence of rescue-apparatus, and asking whether he would take measures to ensure that such breathing-appliances should be available in the future under like circumstances. That question, in his (Mr. Thacker's) opinion, clearly showed an exaggerated estimate of the utility of the apparatus, and a want of appreciation of its essential limitations; for, given an apparatus so perfected as to ensure the safety of the wearer, and given a body of men trained in its use, there still remained the problem of the rescue of the men, if any, remaining alive in the workings, and their removal through the irrespirable atmosphere filling the roadways of the mine after an explosion. This would require a very large number of appliances to be instantly available; or, alternatively, the rescue-corps must have means of keeping alive any men whom they might discover, pending the restoration of the ventilation.

At the same time, there were many instances on record of men remaining alive in the workings for a considerable time after an explosion, and it would be of the utmost value to the officials concerned, after such an unfortunate occurrence, and would add confidence in their conduct of the necessary means of restoration, could they but know the conditions prevailing underground with the minimum amount of delay. It was, he thought, in this preliminary exploration-work, and in dealing with underground fires, that the great future value of such appliances lay; and they as an Institute were indebted to Prof. Hill for bringing the subject before them, and for the time and thought that he and other investigators had spent in perfecting rescue-apparatus.

Mr. W. F. Clark (Aldridge) said that there was considerable force in the previous speaker's remarks. He (Mr. Clark) had formed one of a rescue-party after the Swaithe Main explosion, wherein 167 lives were lost, and, from his experience, if the apparatus were to be of any real service after an explosion, a large number would have to be at hand, so that they could be taken down to the men in the pit, the air of which fouled very quickly.

In the Maesteg district of South Wales, it was estimated that within easy access of Maesteg there were about 12,750 men employed in the collieries. In the Ogmore and adjacent districts, reaching as far as Pyle, there were about 4,300 men employed. The estimated cost of erecting a station was £3,000; and, assuming the output of coal from the district to be 4,000,000 tons annually, this would give a tonnage cost of 0·18d. payable *pro rata* according to output. The yearly cost of maintenance was estimated at £600, which on the same output gave a tonnage cost of 0·036d.

Evidently the coal-owners considered these appliances likely to be of considerable use, or they would not make the outlay.

Mr. Alexander Smith (Birmingham) mentioned the case of a soldier who had become entangled in the wreckage of a military balloon and partly asphyxiated, and had speedily revived through the inhalation of oxygen from an ordinary cylinder used for lantern purposes. He therefore asked Prof. Hill whether some appliance attached to the cylinders of rescue-apparatus could be utilized for restoring the still living but unconscious men.

Prof. Leonard Hill (London), replying to the discussion, said that special attention had been paid to the question of taps, and that the oxygen-cylinders were now provided with taps that permitted no leakage to take place, so that the charged cylinders might be kept in store for some time and be relied on when it was [redacted]

coal-dust had been too much in amount to fire; such had been the case in the Courrières disaster. It would be almost impossible to rescue these men otherwise than by establishing ventilation, as it would be of little use carrying men through long tracts of after-damp, if unprovided with breathing-apparatus. The rescue-party possibly might carry some light form of apparatus, such as the small Pneumatogen apparatus, to the men who had to be rescued, and thus enable them to pass through the zones of foul air and reach the shaft.

A cordial vote of thanks was accorded to Prof. Leonard Hill for his paper, and to Mr. William Charlton for his important contribution to the discussion.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
FEBRUARY 8TH, 1908.

MR. JOHN H. MERIVALE, PRESIDENT, IN THE CHAIR.

The ACTING SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on December 28th, 1907, January 25th, 1908, and that day; together with the proceedings of the Council of The Institution of Mining Engineers at their meetings on January 15th, 1908.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. WALTER HULL ALDRIDGE, Chief Mining and Metallurgical Engineer for [redacted]

Mr. Ernest Henry Potter, Mechanical Engineer, Tilmanstone Sinking, Eythorne, Dover.

Mr. William John Josiah Sandow, Mining Engineer, 17, Fenchurch Street, London, E.C.

Mr. Thomas Thomson, Colliery Manager, Westport Coal Company, Limited, Denniston, New Zealand.

Mr. Wilfrid Ingram Wrightson, Mining Engineer, Neasham Hall, Darlington.

Associate Member—

Mr. Arthur Jamieson Haggie, The Manor House, Long Benton, Newcastle-upon-Tyne.

Associates—

Mr. Charles James Fairbrother, Colliery Under-manager, Warkworth Vicarage, Warkworth, Acklington, S.O., Northumberland.

Mr. Walter Easom Goodenough, Overman, 3, Parkside, Durham.

Mr. Walter Reginald Lascelles, Surveyor, Horden, Sunderland.

Mr. James Edmund Marr, Colliery Under-manager, High Spen, Newcastle-upon-Tyne.

Mr. John Whinn, Colliery Under-manager, High Spen, Newcastle-upon-Tyne.

Students—

Mr. Oscar Earnshaw, Mining Student, Kiln Bank House, Amble, Acklington, S.O., Northumberland.

Mr. John James Turnbull, Jun., Mining Student, Cowpen Colliery Office, Blyth.

DISCUSSION OF MR. H. W. G. HALBAUM'S PAPER ON "CAST-IRON TUBBING: WHAT IS ITS RATIONAL FORMULA?"*

Mr. Frank Coulson (Durham) said that the rational formula for tubbing might apply to a certain number of cases, but the conditions in almost every case were different, and, personally, he thought that Prof. William Galloway's formula was the best, whereby the necessary strength of the tubbing was calculated, and it was left to the engineer to decide what margin to allow for strength, corrosion, etc. Mr. Halbaum intimated that the first factor was the corrosion, and if a pit was intended to last for a certain number of years, that was the factor of corrosion. They did not know, however, that the same amount of corrosion took place every year, and in his (Mr. Coulson's) opinion this was not so. He thought that it was some years before corrosion took place to any considerable extent, and probably the further it got into the cast-iron the slower was its action. Mr. Halbaum made

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 567.

no mention of the mixture of metal in the formula, but they all knew that certain mixtures of cast-iron were very much weaker than others; in fact, some would scarcely resist water. Mr. Halbaum seemed to think that it was quite a new thing to have a specification for tubbing; but, speaking from a knowledge extending over a period of thirty-five to forty years, he (Mr. Coulson) did not know of any tubbing made in this district without a specification giving the mixture of metal, method of making and cooling it, and the best means for testing it. If such a specification were prepared and carried out, he did not think that there was any need for an allowance for faulty castings, because it was almost impossible that there would be a faulty casting. It was suggested that the old method of tubbing with sheeting and wedges was obsolete, and that the proper method was to use bolted tubbing, packed with cement. So far as it went, that was right, but there were certain conditions when bolted tubbing would be an utter failure; and he did not know of any case where tubbing, packed up with cement in the way suggested, had been absolutely successful in keeping the pressure off the tubbing itself. It was, however, sometimes successful when allowing the water to pass up or down, but it was quite possible to meet with a pressure of water from a lower feeder very much in excess of the pressure due to the level of the water in the pit, and several accidents had occurred from that cause. Sometimes if a lower feeder, coming from a much higher [redacted]

Mr. H. W. G. Halbaum (Birtley) wrote that he was pleased to see that his theoretical paper had anticipated so many of Mr. Coulson's practical objections. The author did not profess to be an authority on corrosion, nor did he at present know anyone who was. But Mr. Coulson, who had had a singularly wide experience in that direction, thought that it should be left to the practical engineer to decide the precise allowance to be made in any particular case. Well, that was the actual position adopted in the paper: the arbitrary numerical values usually employed were denounced, and it was plainly shown that the total corrosion effected during a pit's life might, according to local circumstances, be anything from zero upwards. Mr. Coulson argued that the rate might not be uniform: that corrosion was probably slower at first, quicker afterwards, and then slower again. But, on the other hand, Prof. Louis thought that the rate would be quickest of all during the first year.* But both gentlemen agreed that the author had taught that corrosion was always inevitable. Comparing their opposite views, it was manifest that one of them, at least, must be wrong with regard to the rate; whilst, with regard to the point upon which they agreed, a reference to the paper would show that both alike were wrong, as the author had never taken the position imagined. That showed, first, that these gentlemen had not examined sufficiently carefully the paper which they had criticized; and, secondly, how great was the need for that systematic collection of data which the author had urged members to supply. Until that was done, the only course open to engineers was to deal with the average rate of corrosion over a number of years, as deduced from the scanty data already obtained from a few cases where the total corrosion during a number of years was given in bulk—hence the insertion in the formula of a corrosion-member in simple terms. Those terms were rational terms, simply because they were the only terms in which the present state of knowledge permitted the quantity to be stated.

With regard to the alleged overlooking of the effect of various mixtures of metal, it could not, owing to the aforesaid lack of data, be taken into the formula as a specific term. But a very casual inspection of the paper would show that the matter had

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 624.

not been lost sight of, as, in enumerating the principal data required, it was distinctly suggested,* under a separate head, that the quality of the iron corroded should be included in the list.

As for the customary specifications of tubbing mentioned by Mr. Coulson, the author gladly apologized if he had inadvertently withheld credit where credit was due. But, on the other hand, he was equally pleased at last to find a point upon which he could agree with Prof. Louis, namely, that of the sheer unreasonableness of what that gentleman had called "double-barrelled specifications."

The charge, however, of taking for granted that metal of double thickness was doubly strong to resist pressure, could not be sustained against the author, since none of the formulæ, precise or approximate, propounded by him proceeded on that assumption—a fact which Mr. Coulson could easily prove for himself by subjecting the said formulæ to a few simple tests. The charge could only be sustained against the defenders of those "thin"-cylinder formulæ which the author had condemned. But, having regard to Mr. Coulson's correct attitude in that respect, it was surprising that he should declare his preference for one of those formulæ proceeding on the very assumption to which he objected—a formula, in fact, which was worse than even the ordinary "thin"-cylinder rule, since it assumed that a double thickness of metal would actually satisfy the conditions of more than the double pressure.

[redacted]

he hardly understood Mr. Coulson's precise attitude towards the bolted and cement-packed tubbing. Did Mr. Coulson's objections lie chiefly against the bolts? If they did, the writer agreed with him to the extent that he did not approve of them as permanent fixtures. If Mr. Coulson did not see all that lay behind that qualification, the writer would be happy to explain, although he feared that the explanation would not immediately secure Mr. Coulson's approval. Secondly, did Mr. Coulson's objections lie chiefly against the solid cement-packing? If so, would not the same objections lie against close-topped tubbing? If not, would Mr. Coulson kindly explain, for the writer's information, why not? Mr. Coulson could be very sure that the writer was asking these questions in the most earnest and respectful spirit.

With regard to the blowing out of the tubbing at a German mine, described by Mr. Coulson, was that not clearly the result of underestimating the pressure? Was the pressure anything more than the pressure due to the head of water, measured from the outcrop of the water-bearing strata? The object of these last questions was no secret; it was to ascertain whether the blowing out of the tubbing was due to the insufficiency of the formulæ, to the bolting and packing of the tubbing, or to the oversight of the engineers. No doubt Mr. Coulson would agree that the pressures on the cement-packed tubbing should be calculated in the same way as the pressures on a close-topped tubbing, and by Rankine's formula.

Mr. Coulson had finally asked the author whether he would make all the flanges of equal thickness, irrespective of diameter or depth. Possibly Mr. Coulson intended that as a good-natured pleasantry, but whether that were so or not, the writer would respectfully reply: That in this or in any other structural design, his aim would be to erect an edifice which, from the mechanical point of view, should be symmetrical: to the best of his ability, he would aim at safety, strength, and economy, neither mistaking weakness for economy, nor extravagance for safety, nor yet confounding redundancy with strength.

Prof. W. Galloway (Cardiff) wrote that Mr. Halbaum had asked several questions in his reply to the discussion on his

(Mr. Halbaum's) paper, to which he (Prof. Galloway) might perhaps be allowed to reply as follows:—

(1) The formula given by Prof. Louis and himself was incorrect, in so far as a + was substituted for a – in the denominator.

(2) He had never proposed any other formula. He had stated that it was taken from Mr. Haton de la Goupillière's book on Mining,* but printed with the wrong sign in the denominator.

(3) Mr. Halbaum was in error when he stated that he (Prof. Galloway) desired to amend this formula further than by changing the sign in the denominator.

(4) He (Prof. Galloway) had pointed out that it was exactly the same as Mr. Halbaum's formula, when the latter was divested of the allowance for corrosion and 1 substituted for 1·6 in the second member of the denominator.

(5) The reason why he (Prof. Galloway) did not sooner correct the error of the sign in the denominator was simply that he had no occasion to make use of the formula (having ceased to lecture on the subject soon after it was published), or to compare it with the original, until its identity with Mr. Halbaum's had struck him.

(6) He (Prof. Galloway) had quoted three formulæ: Lamé's, the mathematically exact one; a second, more simple than Lamé's, but arrived at by a similar course of reasoning; and a third, derived from the second by eliminating the negligible quantity from the denominator; and he had shown that, in adopting a

[redacted]

demned them in times gone by; but he would once more point out that formula (B)* constituted the essential substructure of Mr. Halbaum's "rational" formula, and that, therefore, whatever charges of incorrectness might be brought against it, the same charges applied with equal force against the so-called "rational" formula.

DISCUSSION OF DR. JOHN MORROW'S PAPER ON "THE STRENGTH OF CAST-IRON TUBBING FOR DEEP SHAFTS."†

Prof. Henry Louis (Armstrong College, Newcastle-upon-Tyne) expressed the obligations under which the members of the Institute were to Dr. Morrow for the excellent work that he had done. It was the first time that anybody had tried to work out the subject of tubbing properly and to take into account the question of ribs and flanges, which obviously played an important part; in fact, when it came to practical tubbing, he did not see how one could work out the subject without taking them into account. It was a very difficult subject, and it might be ungracious to criticize Dr. Morrow's excellent work, but he would like him to go further into detail on one point, which he thought was not quite clear. Dr. Morrow had treated the tubbing as though a ring made up of individual segments were the same thing as a continuous ring. It was obvious that with sheething and wedges, as in what he would call the English system, a ring of tubbing could not transmit forces of tension, but only forces of compression; but in the few records which he had of tubbing actually failing under pressure, as when the rings of tubbing failed when being forced down to great depths by means of hydraulic pressure in a German method of going through quicksands, in all cases it had been proved that the tubbing was squeezed oval before it gave way. A recent work by Mr. J. Riemer‡ threw some light on the subject. A ring of tubbing could not be squeezed oval unless strains of tension as well as of compression were set up. He (Prof. Louis) thought that it might be best to treat the tubbing

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 622.

† *Ibid.*, vol. xxxiv., page 100.

‡ *Shaft-sinking in Difficult Cases*, by Mr. J. Riemer, London, 1907.

as though each segment were a portion of an arch abutting on the other segments. Dr. Morrow stated that this was not necessary for the investigation of the subject, but he dealt with the question rather briefly; and it would be advantageous if he could elaborate the theme, and give his reasons why the arch formula was not necessary, and why the ordinary ring formula with the modifications which he had introduced could safely be employed. As regarded specifications for tubbing, referred to by Mr. Coulson, he (Prof. Louis) was rather pressing a fad of his own in suggesting that a man who wanted material of any kind, whether for tubbing or anything else, had no right to put a specification of that kind before a manufacturer. He had every right to say that he wanted, for example, cast-iron of a certain tensile strength, crushing strength, resilience, or anything else that he pleased, but surely the composition of the metal should then be left to the iron-founder. The manufacturer should be instructed that material was required which would stand up to certain definite tests: and it was the manufacturer's business to devise the composition best fitted for it. He was entirely opposed to the idea of what he might term "double-barrelled" specifications, that was, specifying the composition of the material on the one hand, and its strength on the other. The right way was to leave to the manufacturer the former, of course reserving the right of testing a certain number of pieces either to destruction or partially, in order to make sure that it did come up to the

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tubbing, for a depth of 300 feet and a diameter of shaft of 12 feet, would be 1·44 inches.

If the segments were always perfectly cast, and of simple pattern, that was, without ribs, the problem of thickness would be a simple one. Any formula, in order to be trustworthy, must be conditioned by the design of tubbing-segment used, and must be based on actual experiment.

Mr. G. C. Greenwell's wellknown formula was as follows:—

$$t_1 = \frac{P_1 \times D}{50{,}000} + 0{\cdot}03;$$

in which t_1 was the thickness of the tubbing in feet; P_1, the pressure in pounds per square inch; and D the diameter in feet. It was evidently founded on, and was effective only for, the type of tubbing in use at the time at which Mr. Greenwell wrote his book.* And, so far as he (Prof. Redmayne) was aware, no single case of rupture could be attributed to insufficient thickness, in the first instance, of tubbing put in in those days: that was, tubbing of the pattern on which the formula was founded. Of course, corrosion had doubtless reduced the thickness in many cases, and had necessitated renewal on that account.

Dr. Morrow very rightly drew attention to the fact that the head of water at any one point was not necessarily that due to the vertical depth from the surface at that point; but was, in the case of water-bearing strata lying between impervious beds, the height of the outcrop of such bed above the point in the shaft, which might be very different, and necessitated a levelling being made before this factor in the calculation could be determined.

The question of great depth had seldom, if ever, come into consideration when putting in cast-iron tubbing, as the lower beds penetrated in sinkings were rarely so charged with water as to necessitate the feeders being tubbed off.

What would be of equal value to the determination of the true thickness of tubbing necessary, would be the determination of the resisting strength offered to external pressure by a column constructed of cast-iron segments of built-up and wedged tubbing, simulating, in all respects, a tubbed shaft.

Mr. C. Pilkington (Clifton) wrote that it was necessary now, when so many shafts were being sunk through water-bearing

* *A Practical Treatise on Mine Engineering*, by G. C. Greenwell, second edition, 1869, page 171.

strata, that the question of the thickness of tubbing should be thoroughly discussed. The old engineers worked out their formulæ, regarding tubbing as a plain shell, and took no count of the ribs and flanges. Had these formulæ been anything like similar, they would have satisfied most engineers, if each segment of tubbing (having regard to its thickness of metal and the diameter of the pit) had had its relative size of flanges and ribs assigned to it; but, to say that flanges and ribs did not add to the strength of the tubbing was, he thought, wrong. Dr. Morrow's plan seemed to be sound. All the formulæ only gave the thickness under normal conditions, that was, water-pressure; and extra allowances for strain, corrosive action of different waters, length of time that the tubbing had to stand, and other local conditions, were necessarily decided by reference to the local conditions of each sinking.

Prof. JOHN PERRY (Royal College of Science, London) wrote that he was inclined to think that there was not much use in applying complex mathematical theory to the question of tubbing, nor need each section be more elaborate than a flanged rectangle, 3 feet high, and of suitable length. If t was the average thickness in inches; d, the diameter in inches; p, the pressure in pounds per square inch; f, the working stress, say, 10,000 pounds per square inch; then f equalled $pd \div 2t$ was a sufficiently accurate formula in all cases. The real difficulty was that p [redacted]

(1) To calculate the necessary thickness at any given depth by means of formula 11 for thick cylinders (section 11),* using a factor of safety of, say, 4, or more if the nature of the ground required it.

(2) To add a minimum of ¼ inch or any intermediate thickness up to a maximum of 1 inch, that the responsible engineer might think desirable.

(3) To neglect the additional strength due to the flanges and, say, one vertical and one horizontal rib in each plate, and treat it as an "error on the side of safety." (See paragraph 1 of section 4).†

(4) To make the thickness from the upper edge of the cylinder down to the horizon at which the calculation gave a thickness of, say, 1 inch, uniform—and this depth, of course, varied inversely as the diameter.

Formula 11 was identical with that given by Prof. H. Louis and himself (see section 11),‡ except that the sign of the second quantity in the denominator was corrected and the quantity itself was divided by 2. Their formula with the correct sign was:—

$$T = \frac{WHD}{2(R - WH)};$$

in which case T was the thickness required in inches; W, the weight of a cubic inch of water; H, the height of the column of water in inches; D, the internal diameter of the shaft in inches; and R, the ultimate strength in pounds per square inch of the material employed, divided by the factor of safety. Dr. Morrow showed by calculation that, as he (Prof. Galloway) had pointed out on a former occasion, the second quantity in the denominator was so small that it might be neglected when cast-iron tubbing was in question, and that its omission made practically no difference in the calculated thickness obtained by means of what he (Dr. Morrow) claimed to be the mathematically correct formula, section 10*a*.§

The remainder of the paper was occupied with discussions on: other theories of the thick cylinder (section 13), resistance to collapse (sections 15 to 19), stability of the stiffening rings (sections 20 and 21), plate formulæ (section 22), hoop stress (section 23), stress due to weight (section 24), corrosion (section 25) and prac-

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 109.

† *Ibid.*, page 102. ‡ *Ibid.*, page 109. § *Ibid.*, page 109.

tical results and conclusion (sections 26 to 31). Although the whole of these sections were useful in throwing light upon the general question, the only one (apart from section 25) to which he need refer in this place was section 20, in which a very useful formula (29) was given, together with a table to be used in connection with it for calculating the thickness required, on the assumption that the dimensions of the spaces between the horizontal rings and vertical ribs, and the width and thickness of the rings themselves, were determined beforehand.

Mr. H. W. G. Halbaum (Birtley) wrote that Dr. Morrow's paper required time for its adequate consideration, and, so far, he had not felt able to agree with all its conclusions; but he was very much pleased with the suggestiveness of the paper. It would be a great advantage if some gentleman could supply an historical account of the subject; but that, he supposed, would be very difficult, since, so far as he was able to gather, the early history of tubbing design, and tubbing operations, and of the earlier tubbing failures and successes, had never been written, either in fragments or otherwise. The present position was a singular one. They had a tubbing-plate of a certain design, and were endeavouring to find a formula to fit it. In the ordinary case of engineering, the formula came first and the design afterwards—or rather, the design was expressed first in the abstract formula, and then in the concrete casting. In the case of tubbing, on the contrary, they [redacted]

(3) provision against corrosion, and (4) allowance for imperfect castings, it was sufficient for practical purposes.

The paper alluded to equation (10*a*) as "the accurate formula."* About that, he (Mr. Halbaum) was not very sure. Prof. A. Jamieson had stated that to construct an accurate formula for thick cylinders was simply impossible, and in his opening sentence Dr. Morrow appeared to have stated pretty much the same thing. Prof. Jamieson, moreover, stated that the most nearly accurate method was the hyperbolic method—a method adopted by himself (Mr. Halbaum), and illustrated in Dr. Morrow's formula (16). The same formula had been deduced without the aid of the calculus employed by Dr. Morrow, as would be seen by referring to Appendix III. of his (Mr. Halbaum's) paper on "Cast-iron Tubbing: What is its Rational Formula?"† Dr. Morrow stated that the hyperbolic formula (16) was based on an assumption known to be untrue. So were all other thick-cylinder formulæ, or the desired accurate solution would not be the impossibility which Prof. Jamieson and Dr. Morrow had declared it to be.

But within the limits, between which the operation of any tubbing formula must for ever be confined, the hyperbolic formula (16) "based on an assumption known to be untrue" gave practically the same results as the accurate formula (10*a*). If the stress diagrams due to the two formulæ were constructed, the area of that due to the formula (10*a*) was contained in a trapezium, whilst that of formula (16) was a hyperbolic area. The area of the trapezium was equal to the product of the length of the hyperbolic area and half the sum of the end ordinates of the hyperbolic curve. And as the hyperbolic curve obtained from any possible diagram of tubbing stresses was very nearly a straight line, it followed that the area of the one diagram very nearly equalled the area of the other. For his own part, he still thought that the hyperbolic formula (16) expressed the greater approach to accuracy, and that the formula (10*a*) was valuable inasmuch as it furnished an approximation to the truer rule (16). As a pair of rules applicable to the tubbing case, however, there was practically nothing to choose between them.

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 109.

† *Ibid.*, 1907, vol. xxxiii., page 607.

The formula (11) was really an approximation to the hyperbolic formula (16), proceeding on the assumption that:

$$\operatorname{Log}_e \frac{r_0}{r_1} = \frac{2(r_0 - r_1)}{r_0 + r_1};$$

which was very nearly true within the limits of the tubbing case, and also for some little distance beyond those limits. Dr. Morrow, however, was in error in supposing that Prof. W. Galloway's formula (whichever revision of it were taken) was of the form of equation (11). Prof. Galloway's latest rule (it was really Mr. Atkinson's) was of the form of equation (12). At no time had it ever been of the form of equation (11). Mr. Atkinson's rule was of the form of equation (12), because:

$$t = \frac{p_0\, r_0}{q_1} = \frac{p_0\, r_1}{q_1 - p};$$

because $r_0 = r_1 + t$; and it was always Mr. Atkinson's rule, until Prof. Galloway claimed it.

There was only one rule known to him (Mr. Halbaum) of the form of equation (11), and that was his own approximation to the mean of the standard formulæ quoted in his own paper. For, to quote equation (11) and reduce it, they got:

$$t = \frac{p_0\, r_0}{q_1 - \frac{1}{2}p_0} = \frac{p_0\,(r_1 + t)}{q_1 - \frac{1}{2}p_0}.$$

Therefore: $$t = \frac{p_0\, r_1}{q_1 - 1{\cdot}5\, p_0} = \frac{p_0\, r_1}{q_1 - 1{\cdot}6 p}, \text{ very nearly.}$$

The last expression was the mean of the formulæ alluded to, [redacted]

venience, substituted for the outside radius in the numerator, then $(q-p)$ should be substituted for q in the denominator, so as to maintain the consistency of the natural rule which presupposed the distribution of the stress to be uniform.

Members would, therefore, see that they should not attach undue weight to Dr. Morrow's criticism of the hyperbolic formula (16). Because (*a*) it was supported as against equation (10*a*) by eminent authorities such as Profs. A. Jamieson, W. Lineham, etc.; and (*b*) because, as applied to the tubbing case, the difference of the formulæ was infinitesimal. Besides, Dr. Morrow himself had said that "Equation (11) may be recommended as simple and giving results, under all circumstances, very closely agreeing with equation (10*a*)."* And what was equation (10*a*)? It was, according to Dr. Morrow, the accurate formula. And what was equation (11), so closely agreeing with the accurate formula? He (Mr. Halbaum) would endeavour to show that very clearly, as follows:—

The hyperbolic equation (16) was:

$$\operatorname{Log}_e \frac{r_0}{r_1} = \frac{p_0}{q_1}\frac{r_0}{r_1}.$$

But anyone could prove for himself that within the limits of the tubbing case:

$$\operatorname{Log}_e \frac{r_0}{r_1} = \frac{2(r_0-r_1)}{r_0+r_1}, \text{ very nearly.}$$

Substituting this value of the logarithm in the equation (16), they got:

$$\frac{2(r_0-r_1)}{r_0+r_1} = \frac{p_0}{q_1}\frac{r_0}{r_1}.$$

But from the reduction of formula (12) from terms of r_0 to terms of r_1 to obtain Mr. Atkinson's formula, they knew that:

$$\frac{r_0}{q_1} = \frac{r_1}{q_1-p_0}, \text{ very nearly;}$$

and substituting this value in the previous expression, they obtained:

$$\frac{2(r_0-r_1)}{r_0+r_1} = \frac{p_0\, r_1}{(q_1-p_0)r_1}.$$

But r_0-r_1 equalled t, and r_0+r_1 equalled $2r_1+t$, and consequently:

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 109.

$$\frac{2t}{2r_1+t}=\frac{p_0}{q_1-p_0};$$

$$2p_0r_1=t(2q_1-3p_0)$$

and they finally obtained:

$$t=\frac{p_0\,r_1}{q_1-1\cdot5\,p_0}.$$

This was Dr. Morrow's equation (11) reduced to terms of the inside radius, as previously pointed out. This equation, as Dr. Morrow had pointed out, could be recommended as giving results very closely agreeing with the accurate formula (10*a*). Nevertheless, it was deduced from the hyperbolic rule (16), which was, again according to Dr. Morrow, "based on an assumption known to be untrue."* For his own part, therefore, he (Mr. Halbaum) saw no real reason why anyone should renounce his faith in the hyperbolic rule (16), since even its opponents admitted that it agreed under all circumstances very closely with the accurate formula (10*a*). Especially was this so, when one remembered that even the so-called "accurate formula," along with many other formulæ, was not absolutely accurate, but only an approximation, made as carefully as the present state of knowledge permitted it to be. For example, the last value of t stated was deduced from the so-called accurate formula by Dr. Morrow, and again deduced by him (Mr. Halbaum) from the hyperbolic formula (16) which Dr. Morrow condemned.

Dr. Morrow had further stated (section 20†) that he could [redacted]

been found necessary to check Sir William Fairbairn's rule by a limiting-formula, the limit imposed being the natural safe crushing strength of the metal. Otherwise, for short tubes, or for tubes over-ringed, Sir W. Fairbairn's rule allowed a working-pressure which was absolutely dangerous.* Furthermore, a very high authority, Sir John Anderson, had pointed out† that surplus material in any structure whatever, so far from being a source of strength, was really a source of weakness: the effect being, not that the weaker portions transmitted their stresses to the stronger (as Dr. Morrow appeared to imply in section 5), but that these stresses concentrated themselves on the weaker portions, the result being that all the elastic work or most of it was done by the weaker parts of the structure. It was the observance of this principle which had led him (Mr. Halbaum) to recommend that, in the design of tubbing-plates, the ribs should be as few in number and as slender in bulk as might be deemed possible, having regard to the required stiffness on the one hand, to the efficiency of the castings and the distribution of the stress on the other hand. The tubbing should be stiff enough, no doubt, but it should not be forgotten that every stiffening-ring was a natural enemy to good casting and to the desired uniform distribution of the stresses in the material.

He (Mr. Halbaum) had at first been unable to identify Dr. Morrow's "plate formulæ" with Prof. W. C. Unwin's formula for rectangular plates. But, the identity being established, Prof. Unwin expressly stated that any arching or dishing of the plates altered the conditions considerably. This, of course, Dr. Morrow had admitted, but stated that the error, so far as the tubbing case was concerned, was on the side of safety. That might be true; but the object of the engineer should be to combine safety and economy, and Dr. Morrow's plate formula simply obtained the one at the expense of the other. It not only ignored the extra strength due to the curvature of the plates, but had to depend on the tensile instead of on the compressive strength of the cast-iron. Such a proceeding might be safe, but it could hardly be called by the name of practical engineering.

* *Practical Engineer Pocket-book*, 1903, page 114.

† *Strength of Materials*, pages 155 *et seq.*

The ring formula suggested for use in conjunction with the plate formula had provided him (Mr. Halbaum) with considerable food for reflection, but his present attitude was that of the open mind. The formula might perhaps be applicable to a complete ring of tubbing, but he was quite unable to perceive the economy in any design afforded by the application of formula (25) to the imaginary ⊥ ring having the section shaded in Dr. Morrow's fig. 5 (plate ii.). The thickness of the ring, so designed, would be the same as if the unshaded section of the segment were not there. Such a ring would come out in dimensions unduly extravagant. At any rate, one could not, in the absence of further information, help thinking that such would be the result.

It seemed a pity that Dr. Morrow had not, for the benefit of the members, more fully exhibited and investigated the grounds of the ring and plate formulæ. Prof. M. Lévy might be a reliable authority, and Prof. Unwin undoubtedly was, but it was not possible nowadays to accept formulæ on authority alone. Engineers were becoming increasingly desirous to understand the principles, physical and mathematical, upon which such formulæ reposed. But Dr. Morrow's two principal formulæ were hardly supported in that particular way, and until they were, one was obliged, in justice both to Dr. Morrow and himself, to hold his judgment in suspension.

In conclusion, it must not be supposed that, in offering the foregoing criticisms, he had any wish to depreciate the value [redacted]

out. If the relative values of the plate and ribs could be assigned, considerable progress would be made, as there could be no question of the desirability of basing the calculation on the modulus of elasticity in preference to the ultimate strength. Without pretending to criticize the theories and deductions by which Dr. Morrow obtained his principal rule (29), the theories apparently required further confirmation, and the experiments which had been conducted might not afford an exact parallel to shaft-tubbing. That the thickness of the metal should increase only as the cube root of the pressure was too revolutionary a theory to be impulsively accepted. Practical experience counted for something; and, so far as he was aware, there had been no failures of segments where a reasonable factor of safety was allowed with the thin-cylinder rule, provided that a proper allowance was made for deterioration, and that the flanges were such as to afford a low factor of safety by the plate formula. Taking the case of the failure of tubbing at Garforth collieries, described by Mr. R. Routledge,* the tubbing in a shaft, 12 feet in diameter, was originally $\frac{3}{4}$ inch thick throughout for a length of 225 feet. The segments were 3 feet $10\frac{1}{2}$ inches long and 2 feet high, had one intermediate horizontal rib, and were badly fixed. It was fair to assume that the head of water was approximately of the height of the tubbing or, say, 110 pounds per square inch. The value of k by Dr. Morrow's rule could not be less than 0·002 for such a segment, and if the thickness of the metal were calculated by rule (29), without allowing any factor of safety, it was $[0{\cdot}002 \times 72 \sqrt[3]{110} =] 0{\cdot}68$ inches. When the tubbing burst, 50 years after being placed in position, the metal was said to be only about $\frac{1}{8}$ inch thick and poor in quality.

The plate formula (30) was useful to test whether the ribs and flanges were arranged sufficiently near together. The tank formula given by Sir Guilford L. Molesworth was practically identical with that given by Dr. Morrow. It was as follows:—†

$$t = \frac{a^2 b}{100} \sqrt{\frac{p}{a^4 + b^4}} + 0{\cdot}25.$$

A factor of safety of 4 was apparently allowed for in the formula, and 0·25 inch was added, doubtless for casting flaws.

* "The Garforth Collieries, with Special Reference to the Failures of the Tubbing," etc., *Trans. Inst. M. E.*, 1895, vol. ix., page 150.

† *Pocket-book of Engineering Formulæ*, twenty-fifth edition, 1907, page 314.

With regard to the width and thickness of the flange, Sir Guilford L. Molesworth gave the following formula:—(*a*) When the width (including plate) was four times the thickness of the flange:

$$t=0{\cdot}0143\sqrt[3]{pa^2b};$$

and (*b*) when the width was five times the thickness of the flange:

$$t=0{\cdot}0127\sqrt[3]{pa^2b}.$$

In the absence of suitable data for the allowance for corrosion, the figures (Table I.) given by Mr. B. H. Thwaite* were of interest.

TABLE I.—CORROSION OF CAST-IRON, FOR ONE YEAR'S EXPOSURE, PER SQUARE FOOT OF SURFACE.

	Metal as cast. Pounds.	Metal with Skin planed off. Pounds.	Metal with Surface Galvanized. Pounds.
Sea-water, foul	0·0656	0·2301	0·0895
,, clear	0·0635	0·0888	0·0359
River-water, foul	0·0381	0·0728	0·0371
,, clear	0·0113	0·0109	0·0048
Air, pure	0·0113	0·0109	0·0048
,, manufacturing district, or at sea	0·0476	0·0884	0·0199

Dr. JOHN MORROW (Armstrong College, Newcastle-upon-Tyne) wrote, in reply to the discussion on his paper, that Prof. Perry had called attention to the uncertainty which must always exist as to the actual magnitude of the pressure applied to the tubbing. Considering material having [redacted]

calculation. The lower section was evidently under quite different conditions, and the observed water-pressures were less than half those obtained by calculation. The greatest depth at which the pressure was recorded was 214 feet 5 inches, and the water-pressure there was 45 pounds per square inch. This corresponded to a pressure of $0·21h$ pound per square inch, and was much in excess of Prof. Perry's estimates. It was important to remember, as pointed out by Mr. Coulson, that several accidents had occurred owing to the pressure of water from a lower feeder being very much in excess of that due to the level of water in the pit. In this connection Prof. R. A. S. Redmayne's remark might be recalled, concerning the freedom of the lower beds from water. One of the causes of this absence of water in appreciable quantities was that the outcrop of a deeply-seated bed was usually far distant from the site of the sinking; the faults and fissures occurring in the water-bearing strata might then not only provide an excellent system of drainage, but give a new level below which the depth of water should be measured. It appeared, therefore, that, in order to acquire a more accurate knowledge of the value of p, it was necessary that a large number of observations, similar to those conducted by Mr. Isaac Hodges, should be made; and that in each case the geological conditions should be carefully considered.

It would be noticed that the author was not entirely in agreement with Prof. Perry as to the simplicity of the calculation necessary to ensure a sufficient thickness of casting, although the formula given by Prof. Perry (in which t was the average thickness) was the same as those stated more fully in the paper as formulæ (31) and (32).*

Prof. Louis had presented some difficult questions, and it would only be possible to indicate the nature of the answers. Wedged tubbing could not transmit tensile forces at the joints; but, since these joints were under pressure, it would be possible for a large variation of stress-distribution to occur without tensile stresses being thereby introduced. Further, owing to the great width of the vertical flanges (compared with the thickness of the shell), considerable tensile-stresses might occur in the castings without the stability of the joints being endangered. It ought

* *Trans. Inst. M. E.*, 1907, vol xxxiv., page 119.

not to be difficult for anyone with sufficient leisure to obtain quantitative results on this point, and such would, no doubt, be valuable.

With regard to the application of the arch theory, the position was this: If the shaft were truly circular and the pressures purely normal, a proper application of the theory of arches would give a "line of resistance" in the form of a circle passing round the tubbing-ring. This circle would, in position and direction, represent at every point the line of action of the resultant of the compressive stresses found by the thick-cylinder formula. If one tried to draw such a line in the way usual for arches, he would be easily convinced of the truth of the above statement.

When the pressure was not normal, or the ring not circular, the thick-cylinder formula was inapplicable, and the arch methods might possibly be employed; but, in his (Dr. Morrow's) paper, any appreciable deformation from the circular shape was looked upon as failure, and was, therefore, not further considered.

The difficulties of the subject were not inconsiderable, and it was perhaps advisable to point out that, in order to render the writing of the paper possible, the author had limited his investigations to the question of the strength of the castings, and had not considered the stability at the joints. If tubbing, designed by the rules laid down, were subsequently to collapse by displacement of the segments as a whole, rather than by fracture of the material, such a failure would have no bearing on the

[redacted]

reason why the logarithmic formula might be used was because it gave results which agreed more or less closely with the more accurate theory. The reasons why Lamé's theory might be considered satisfactory were clearly stated in the paper.

Mr. Halbaum's remarks were so lengthy that it was inadvisable to reply to them in detail. They frequently carried with them their own condemnation. In fairness to other writers to whom Mr. Halbaum referred it would be sufficient to say: (1) That although Prof. Jamieson had used the logarithmic formula for cylinders under internal pressure, he did not by any means uphold it as more accurate than the accepted theory. (2) That Prof. Lineham did not appear to have used the logarithmic formula at all, but gave (in his text book*) the correct theory for cylinders under internal pressure; that, so far as the author could ascertain, neither Prof. Jamieson nor Prof. Lineham had ever considered the external pressure problem; and that Profs. Lamé and Levy were amongst the greatest authorities on the elasticity and strength of materials. (3) That Sir W. Fairbairn's formula was for the collapse of long cylinders and was not to be mentioned in connection with short or over-ringed tubes. (4) And, finally, that Sir John Anderson had not said anything so absurd as that surplus material, in any structure whatever, was a source of weakness.

Mr. O'Donahue's contribution to the discussion was helpful, but his earlier remarks might be misunderstood. The ribs and flanges did not, of course, weaken the tubbing. The point Mr. O'Donahue brought out was that the structure frequently offered less resistance to deformation (and consequent collapse) than to actual crushing. Thus it was only when deformation was considered that the source of weakness was discovered.

The failure at Garforth collieries, in its relation to equation (29) of the paper, was to be explained on the grounds that the pressure might have been much less than 110 pounds per square inch, that the thickness might have been about $\frac{1}{8}$ inch in some places and much greater in others, and by the more important consideration that equation (29) was for the deformation of an unsupported ring, whereas in the case cited considerable support might have been forthcoming. The paper, by its title, referred mainly to "deep" shafts. There appeared

* *Text-book of Mechanical Engineering*, by Prof. W. Lineham, second edition, 1895, page 399.

to be a general consensus of opinion in favour of neglecting, for such cases, the additional strength imparted to the tubbing by the backing or by any lateral support it might receive.

The author had not noticed Sir Guilford Molesworth's formula when writing the paper, or would have referred to it. When the numerical examples were added to the paper, too much prominence was perhaps given to the plate-formula. The position taken up, as the result of the investigation, was that the formulæ (11), (24), (29), and (32) should be satisfied for deep shafts. Of these, (29) would usually be the determining factor; but, in unusual designs, it might be necessary to test the result by the others. The plate-formula (30*a*) was an additional safeguard, but one which, in the author's opinion, need only be applied under exceptional circumstances. If the designer were afraid that the pressure might not be normal to the outer surface of the shell, he might apply formula (30*a*). Or, again, if the tubbing segments were to be constructed to withstand a "squeezing pressure" of the earth (or strata) of any definite amount, formula (30*a*) should be a safe formula to use.

Section 7 of his (Dr. Morrow's) paper* dealt briefly with the different theories of rupture; but the succeeding sections were based on the assumption that the compressive stress was to be kept within a safe limit. Since writing the paper, he had noticed a simplification which occurred on another assumption [redacted]

and to endeavour to amend it to suit the external-pressure problem. The formula due to Grashof, and erroneously altered by Mr. Halbaum,* was evidently based on a strain-theory of rupture, and was, in the form given, quite inapplicable to the tubbing problem.

He felt that the value of the paper had been materially enhanced by the remarks and suggestions which it had elicited; and, in conclusion, he would like especially to thank Prof. H. Louis, who had first called his attention to the fact that a complete re-examination of the methods of calculating the strength of tubbing was required, and who had given him much assistance in the preparation of the paper.

The PRESIDENT (Mr. John H. Merivale) said that the members were very much indebted to Dr. Morrow and Mr. Halbaum for attempting to treat this very practical subject from a theoretical point of view. There were, however, some subjects so essentially practical that it was almost impossible to treat them theoretically.

DISCUSSION OF PROF. HENRY LOUIS' PAPER ON "A LOCKING HOOK FOR SINKING PURPOSES."†

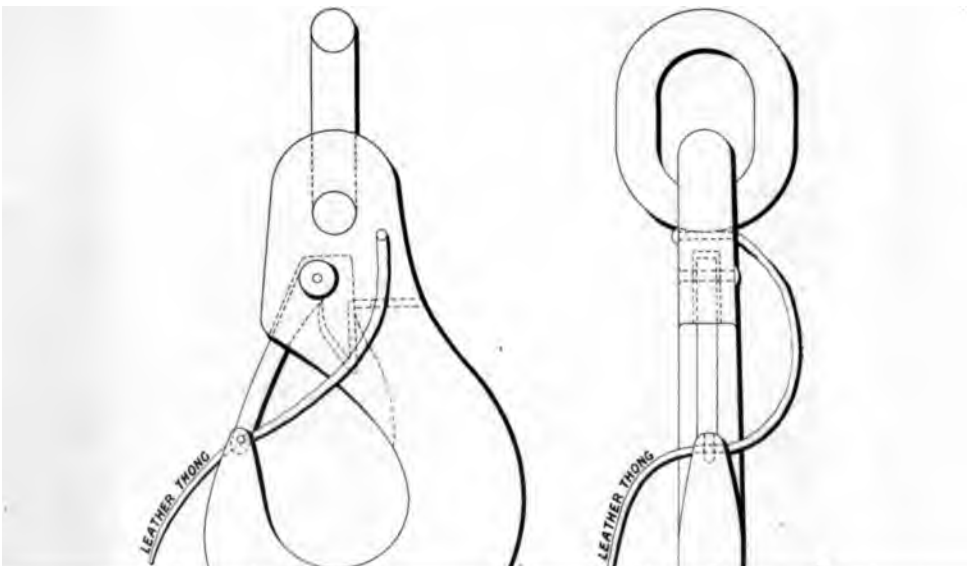
Mr. FRANK COULSON (Durham) said that the sketches of spring hooks in both the paper and the discussion were very misleading, and wrong in construction. It was a good idea to have a spring hook locking, but he did not know of many accidents having occurred with an ordinary properly-constructed spring hook. He had known one case where a kibble came up on the point of the hook, but that was due to carelessness, and ought not to have occurred. There was only one position in which a hook could become detached, and that was when the load was resting. Better than a spring hook was a hook having a hole through the tongue, with a similar hole through the end of the hook, and a leather thong to put through (figs. 1 and 2). This was one of the best and safest appliances: there was necessarily no spring to break, although a spring might be used, and would generally last for many months,

* "Cast-iron Tubbing: What is its Rational Formula?" by Mr. H. W. G. Halbaum, *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 596.

† *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 56.

and it could be quickly handled. With a locking hook, there was a certain amount of danger of the tongue lifting when it became slightly worn.

Prof. H. Louis said he considered that Mr. Coulson's remarks constituted an argument in favour of such a contrivance as was described in his paper; for he (Mr. Coulson) had stated that some accidents had occurred, and it was because there was nearly an accident in a sinking with which he (the speaker) was



[redacted]

but what he wanted was something that would work automatically, whether the men were careful or careless.

Mr. T. C. Futers (Whitley Bay) asked how the kibble got off the hook, if, as he understood, the load was being lifted at the time. With an elongated section, instead of round, it would be easily understood.

The President (Mr. John H. Merivale) also asked how the kibble managed to come up on the point of the hook. Of course, if it could slide on to the point, it could equally slide off it.

Mr. Frank Coulson said that the kibble was just balanced by the bow resting on the point of the hook.

Mr. J. B. Atkinson (H.M. Inspector of Mines) mentioned a case at Usworth colliery* where, for additional safety, belts were placed round the shaftmen and attached to the cage-chains by a spring hook, but yet a shaftman who was stated to be attached to the cage-chains fell to the bottom of the shaft.

Mr. Frank Coulson said it occasionally occurred that a spring hook would fail if it got into a certain position in turning round when the load was resting and there was no weight on it; it was then liable to become detached.

DISCUSSION OF PROF. HENRY LOUIS' PAPER "ON A DEFICIENCY IN THE NOMENCLATURE OF MINERAL DEPOSITS."†

Mr. H. W. G. Halbaum (Birtley) said that, in his opinion, the adoption of Prof. Louis' suggestion would rather increase than diminish confusion, since most men used "pitch" and "dip" as interchangeable terms. Mr. A. L. Steavenson's remarks‡ had been described as facetious, but he (Mr. Halbaum) thought that they contained much solid wisdom, and that Mr. Steavenson intended them more seriously than some appeared to suppose.

The use of the word "pitch" appeared to him quite unneces-

* *Reports of Mr. J. B. Atkinson, H.M. Inspector of Mines for the Newcastle District (No. 3), to His Majesty's Secretary of State for the Home Department, under the Coal-mines Regulation Acts, 1887 to 1896, the Metalliferous Mines Regulation Acts, 1872 and 1875, and the Quarries Act, 1894, for the Year 1904,* pages 49 and 50.

† *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 236. ‡ *Ibid.*, page 238.

sary. Prof. Louis had himself admitted in his paper that all the vertical and horizontal angles stood in a simple geometrical relationship to each other. Moreover, it was hardly correct to say that the quantity now sought to be named "pitch" could not otherwise be defined without a "cumbersome circumlocution." It could be simply stated as the dip of a given bearing, and, popularly speaking, that definition was already a part of our mining vocabulary. It would apply to the strike-normal itself, and to every line making an angle with that line in the same plane—the said plane, of course, being that which contained the line of strike and the line of maximum dip.

Prof. Louis spoke of men who had sunk shafts and failed in their objective because they had overlooked the fact that the dip of the strata was not the same in every direction. They took the "dip" into account, but they forgot the "pitch."* But the simple substitution of one word for another would hardly save such men from error. Neither would they be kept right by the trignometrical equation set forth in the paper.

He (Mr. Halbaum) had previously noted that the question of the precise rate at which the dip varied with the [redacted]

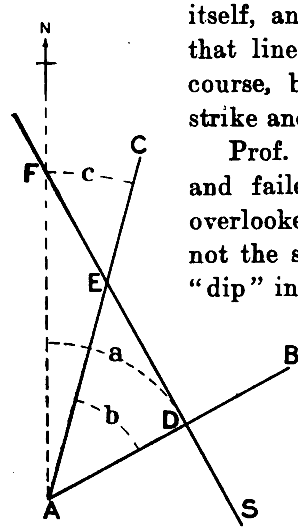


Fig. 3.—Plane Figure connecting Horizontal [redacted]

in the bearing north *a* degs. east. Then, draw the meridian line AN, and set off the full dip line AB at the angle *a* with AN. Let it be required to find the dip of the bearing north *c* degs. east, making an angle *b* with the strike normal AB. Set off this bearing along AC, as shown in the diagram. Now, the dip of the bearing AB was given as 1 in *x*, where *x* was some known numerical value. Let the geometrical equivalent of *x* be AD, and measure that distance off along AB. Now, through the point D, and at right angles to AB, draw the line of strike SF. It cut AC in E, and also cut AN in F. Then the dip of the bearing AC was one in AE; and, similarly, that of AN was one in AF. For since SF was a level line, it was clear that the total vertical fall from the point A to the line SF would be the same by whatever route they proceeded from the one to the other. And, since, by hypothesis, the dip was regular, the dip on any line parallel to AC would be the same as that on AC itself, and so on, for any other line that might be taken. But if they had to start coining new words and phrases—or, what was worse, officially changing the signification of the old words in current use—merely in order to avoid the imaginary difficulty of having recourse to a simple diagram like that, they would, in his opinion, be lowering their own dignity and status as mining engineers.

Mr. E. R. Field (Victoria, Australia) said that in the Bendigo district of Victoria the word "pitch" was universally used to show the dip of the ore-bodies in the direction of the strike of the lode.

He believed that the usage originated in the Bendigo district, where the celebrated saddle-reefs occur. There, the folded country rock generally has an inclination in the direction of the strike of the strata. In the apex of the anticlines, the large bodies of quartz forming the "caps" of the saddles are found, and, of course, have the same inclination, or pitch, as the strata. The "legs" of the saddles, which are downward continuations of the central quartz-body on either side, have the same strike as the cap, and dip away from it in opposite directions.

Both "dip" and "strike" being thus already employed, a further term was necessary to complete the description of the main ore-body. In other parts of the State, where ordinary fissure-lodes

occur, the term "pitch" was found of great service for referring to the inclination of ore-bodies (shoots) in the direction of the strike of the lode. In a fissure-lode which he had been working recently, the pitch of the shoots was only 4 degrees, the dip of the reef being 65 degrees. It would thus be seen that the pitch was the most important factor in laying out development-work.

Mr. H. W. G. Halbaum said that the pitch of the ore-bed would be the dip of the bearing in that direction.

Prof. H. Louis said that he was obliged to Mr. Field for pointing out that the word was employed in Australia in the same sense as that in which he was trying to define it for use in this country. It was also used in the same signification almost throughout the United States of America, and he had just received a letter from Dr. Raymond (the wellknown Secretary of the American Institute of Mining Engineers) in which he stated that he was bringing forward before that body a short paper on practically the same lines, and was advocating that the word should be restricted to this meaning. The word "pitch" had been used rather loosely in the place of "dip," and his suggestion only meant that for the future they should limit its use to the inclination of ore-shoots or ore-bodies, when such deposits went down actually at angles other than the true dip. He was afraid that Mr. Halbaum had entirely missed the point of his paper; he was not dealing, as Mr. Halbaum seemed to think, with inclinations (other than the dip) within [redacted]

DISCUSSION OF MR. WALTER ROWLEY'S "NOTES ON MINING AND ENGINEERING IN AMERICA AND CANADA."*

Mr. WALTER ROWLEY (Leeds) wrote that he had omitted to acknowledge in his paper that the illustrations of the chemical mine fire-engine and of the concrete arching at Burnside colliery† had been reproduced by permission of *Mines and Minerals*, in which paper they had previously appeared.‡

Mr. E. O. FORSTER BROWN (Stoke Bishop, Bristol) wrote that although the number of inspectors in Pennsylvania appeared to be very much greater relatively than in Great Britain, the resulting accidents were altogether out of proportion. That might be partly due to the fact that Pennsylvanian miners were, to a large extent, drawn from a number of different nationalities of probably inferior intelligence to that of the average British miner; but a more forcible reason was that there were fewer precautions taken for securing the safety of the mine. The writer's own experience was that manholes in main haulage-roads were a curiosity, and he had witnessed a set of thirty tubs weighing 5 tons each being run out several hundred yards at a high speed to the mouth of a 4 per cent. grade incline, solely controlled by three trip-riders riding between the tubs.

He (Mr. Brown) agreed with Mr. Rowley that the increased output per miner in the United States of America was due to the thickness of the seams and easy access. With regard to the Connelsville region, however, he would also add that the regularity of the dip of the strata and absence of appreciable faults was a striking feature, and enabled the main haulage-roads to be laid out many years ahead and to the best advantage for dealing with a large output.

With regard to the Niagara Falls, one of the interesting features of the power-houses was the arrangement for dealing with the ice difficulty. The Ontario Power Company had, he thought, adopted plain gratings for the water to filter through. The Electrical Development Power Company, a little farther up the river, had, however, constructed two masonry ice-booms, pierced

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 239.

† *Ibid.*, page 242.

‡ *Mines and Minerals*, 1907, vol. xxvii., pages 469 and 542.

by a series of inlet-arches in the outer boom 8 feet and in the inner boom 6 feet below water level, the arches in the inner boom being also provided with gratings.

The five power companies at present in partial operation would, he understood, eventually produce 700,000 horsepower from one-fifth of the 250,000 cubic feet of water per second flowing over the falls. If the total power could be utilized, it would amount to 3,500,000 horsepower, which, on the assumption that a horsepower-hour on the average required 4 pounds of coal, was equivalent to 50,000,000 tons of coal per annum, and could be transformed by a few hundred persons within an area of a few square miles *ad infinitum*.

It was interesting to compare these figures with the statistics of the South Wales coal-field, where, during 1906, 174,660 persons were employed in producing 47,055,969 tons of coal from an area of 1,000 square miles with a limited life. It would seem that an economical method of storing and transporting electricity should go far towards solving the fuel problem of the future.

A SIMPLE METHOD OF WATER-STOWAGE EMPLOYED AT NO. 5 PIT OF THE ESCARPELLE MINES.*

By SAINTE-CLAIRE-DEVILLE.†

A simple installation has been laid down at No. 5 pit of the Escarpelle Mining Company, in order to make direct observations on the results that can be obtained by means of water-stowage, having regard to the more or less complete filling of the hollows left by working, to the settlement which the strata undergo, and to the influence of the process upon the maintenance of the roads.

The experiment has been tried in a dip-working upon No. 5 vein at the 1,772 feet (540 metres) level (fig. 1, plate ii.). An incline goes down 164 feet (50 metres), along the slope of the seam, and from it are opened out two cuts (*tailles montantes* = cuts or stopes parallel to the dip), 33 feet (10 metres) wide, starting from two secondary roads at the levels of 82 and 164 feet (25 and 50 metres) respectively. At the time when water-stowage was commenced (January, 1905), 131 feet (40 metres) of coal had been removed from the first cut, and 65½ feet (20 metres) from the second, by this method of stoping, and the places stowed in the ordinary way with dirt obtained from working the seam, and with dirt brought in from other parts of the pit, and tipped at the top of the cuts. Seam No. 5 has in this place a thickness of from 60 to 67 inches (1·5 to 1·7 metres); it consists of two beds of coal, each 15¾ inches (0·4 metre) thick, one next to the roof and the other next to the floor; the parting between them consists of black and grey shales, 27½ to 35½ inches (0·7 to 0·9 metre) thick; the mean angle of inclination of the seam is 35½°.

The roof was rather bad in the stopes, especially in the neighbourhood of the upper road of the first cut, which was a pony-

* "Procédé simplifié de Remblayage hydraulique employé à la Fosse No. 5 des Mines de l'Escarpelle," by Mr. Sainte-Claire-Deville, *Comptes-rendus mensuels des Réunions de la Société de l'Industrie Minérale*, 1906, pages 31 to 37.

† Translated by Prof. Henry Louis, M.A.

way, above which the coal had been removed during the years 1901-1904. The maintenance of the inclined roads from the stopes was always rather costly.

The water-stowage was arranged in the two cuts on the return side without stopping regular work for a moment. They were simply transformed into stopes worked upwards off an inter-level road (*tailles chassantes*) 82 feet (25 metres) in width. The coal when cut slips down from stope to stope to the foot. As regards the dirt, the workmen throw it behind them without packing it against the roof.

The first cut employs five men, the second six, the two together getting from 65 to 75 tubs of coal per day. The first cut is stowed directly from the top; the second is supplied by a short row of pipes, which take the stowage from the pony-road (fig. 4, plate ii.).

Stowage.—The material employed for stowing consists of shales from the washery for the first cut, and ashes from the boilers, screened through round holes 0·79 inch (20 millimetres) in diameter, for the second. They are sent down in tubs by the shaft, at the end of the shift after the miners have ridden to bank. These tubs are coupled up to the empty trains, and thus carried, without additional cost, to the double roadway close to the incline, so that they are in readiness for the stonemen's shift at 5 p.m. Each cut is supplied by a hopper of small dimensions, 37½ inches (0·95 metre) high, 40 by 35½ inches (1 by 0·90 metre), or 31 cubic

[redacted]

base of the hopper; the other part flows in at the apex of the hopper, beneath the sliding door, through a horizontal pipe 2 inches (50 millimetres) in diameter, perforated with twenty holes 0·39 inch (10 millimetres) each in diameter, the jets from which carry the material into a series of troughs made of wood lined with sheet-iron, suspended from the mine-timbers and descending into the cut within about 6½ feet (2 metres) of the level of the stowage.

Fixed Hopper.—An identical hopper supplies the second cut. It is stationary, at the head of a passage left in the old dry stowage of the first cut. The water is introduced in the same way, but the supply-pipe has twenty-five holes of 0·47 inch (12 millimetres) diameter, in order to get a bigger water-supply. The apex of the hopper enters a sheet-iron funnel covered by a screen with round holes 2 inches (50 millimetres) in diameter, and attached to a column of pipes of 4·33 inches (110 millimetres) in internal diameter, running along the passage for a length of 82 feet (25 metres), and then by an elbow of 40 inches (1 metre) radius, into the upper road of the second cut, so as finally to pour the stowage into the troughs of this cut. In order to avoid too great a length of pipes, the second hopper will be removed to a new passageway 213¼ feet (65 metres) from the previous one, from which it can supply the stowage for a length of some 230 feet (70 metres), that is, 115 feet (35 metres) on either side.

Obstructions in the Pipes.—Some experiments have been needed, in order to avoid the formation of obstructions in the pipe-line. It has been found necessary to avoid the shales, which were found to be too heavy. Screened boiler-ashes, sometimes mixed with dirt (fragments of bricks, old cinders, or small shale), have given good results. Placing a pipe so as to inject water at the lower elbow in the direction of the flow has also had a good effect.

Water-supply.—The water-supply is taken from a little reservoir 883 cubic feet (25 cubic metres) in capacity, excavated at an incline close to this seam, from which the water is pumped into the pipe-system. The water which has been used carries very little slime with it. It runs down to the bottom of the incline, whence a pump forces it up to the reservoir. The only settling-pit is a sump of 10 feet (3 metres) cube in capacity, from which this force-pump draws; it is cleaned out at long intervals.

Work at the Face (fig. 4, plate ii.).—The stowage is done in each cut upon four cuts (*travées*), or a length of 14$\frac{3}{4}$ feet (4·50 metres). The stowage is kept in place at the bottom of the face by a block measuring 6$\frac{1}{2}$ (2 metres) by 8$\frac{1}{4}$ feet (2·50 metres), of dry stowage, kept in place by timbers. At one side of it a barrier is made up of brattice-cloth strengthened by sheets and planks attached to the timbers. Experience has shown that with the comparatively steep slope of cuts at these mines one should attempt to get a filtering surface sufficiently great to prevent any serious accumulation of water at the surface of the stowage, in order to avoid dangerous overloads capable of breaking through the pillar; the planks must therefore not be put too close together. The barrier is taken down after each series of four cuts has been stowed, in order to be used for the next series. One can then see that the stowage stands perfectly in a vertical wall, and sets quite close against the roof.

Consumption of Water.—The consumption of water, ascertained by a counter placed upon the feed-pump, shows very accurately 1 cubic foot of water per cubic foot of stowage for the shales of the first cut, and 1·65 cubic feet per cubic foot of the boiler-ashes for the second cut. The figure for the first cut may appear somewhat high, seeing that the material is transported in open troughs at an inclination of 35°; in fact, in this case the proportion of water is determined only by the degree of fluidity necessary to cause the material to flow freely into all [redacted]

creased, there is a great risk of leaving hollows. This observation, suggested by experience, justifies the employment of hoppers with gates enabling the flow of shales to be regulated accurately. When the mixture has to be conveyed in pipes, the part played by the water as a transporting medium becomes predominant, and the proportion of water necessary to avoid obstructions is greater than that required to deposit the material. The stowage is then deposited in practically horizontal layers.

Rate of Work and Cost.—The material is, on the average, tipped at the rate of 40 tubs per hour. Two active trammers and an assistant can even work at the rate of a tub per minute, but cannot keep up this pace for any length of time. As a means of comparison, an ordinary trammer took 2½ days to tip and stow 25 tubs of ordinary stowage in the first cut. Hydraulic stowing is carried on by sets of 50 tubs at the first cut, and 30 to 35 at the second. The mining company have not a reserve of water sufficiently great to enable them to do more, and this, moreover, suffices for the need of their workings.

The following is the cost of the stowage calculated in the same way as has been done by Mr. Lafitte for the Lens Collieries, and only taking into account the expenses incidental to this particular process:—

Description.		Labour at the surface.	Labour, tipping underground.	Barriers.	Materials for the barriers.	Total.
		Francs.	Francs.	Francs.	Francs.	Francs.
1st cut	Per cubic metre of stowage	0·141	0·106	0·101	0·050	0·398
	Per ton of coal extracted	0·087	0·065	0·062	0·020	0·234
2nd cut	Per cubic metre of stowage	0·249	0·109	0·095	0·050	0·503
	Per ton of coal extracted	0·163	0·071	0·062	0·020	0·316

N.B.—1 cubic metre is equal to 35·316 cubic feet; 1 franc is equal to 9½d.

Screening the boiler-ashes increases the working-cost for the second cut, without, however, making it prohibitive. The outlay for compressed air is not included, because the steam required is supplied to the compressor by a battery of boilers heated by the waste heat of coke-ovens. It should be added that the maintenance of the tramlines has been diminished by two-thirds, and that the roof of the workings has become much better, so that the cost of hewing has been diminished. The output per man has been increased by about 4 cwts. (200 kilo-

grammes) for each incline. The ridding-out of the pony-road has also been saved, as this road would have been very much broken down in making the first cut by the ordinary method.

Settlement of the Stowage.—Direct observations upon the settlement of the stowage have been recently made in cutting a passage through the first cut, through the stowage, which was then nearly six months old. The thickness of the same had decreased only from 6 to 10 per cent. in different places; the roof has remained perfectly firm, and does not show the slightest break. The shales are admirably packed against it, and form a very compact mass. The dirt from the seam which remained upon the floor is also well packed down. A simple calculation has, moreover, shown that its settlement had been reduced to one-tenth by the flow of water which had passed over them.

There is every reason to suppose that the settlement will be still less in working the second cut, which is operating in a district further removed from the zone of fracture created by the previous workings.

The Application of this Method to any District.—The principle of doing away with pipes can be applied with advantage in thin seams, and will be compulsory whenever a supply of material and water in the upper levels (as in the case of a number of the workings at these mines) is not available. The entire plant required comprises a pump distributing water to the roads, a [redacted]

on, putters, and drivers; and it is only within the limits thus admissible that this simple process is economically applicable With these reservations, it is thought that pits wishing to practise water-stowage in only a small area of their workings can with advantage utilize the methods just described.

Mr. SAINTE-CLAIRE-DEVILLE (Herserange, France) wrote that it might be of interest to the members of the Institute to know that, in consequence of the first experiments noted in his paper, water-stowage had been applied in other districts of the same pit; more particularly, the method of working indicated in the last paragraph of his paper had been employed. Although No. 9 seam, which was being worked, was only about 20 inches (½ metre) in thickness, there had been no increase in working-costs, because the great firmness resulting from water-stowage had allowed of extremely long cuts being made, and, in consequence, considerable expense in cutting and maintaining roadways had been saved.

Personal experience of water-stowage, extending over a period of 2½ years, had brought the writer to the conviction that it very much improved the conditions of the roof of the seams. A roof which might be bad with ordinary working, became good when water-stowage was employed. It also diminished greatly the risk of accidents through falls of stone, and, as a matter of fact, in the eight or ten workings which had been exploited by the new process from January, 1905, to August, 1907, at the No. 5 pit of the Escarpelle mines, no accident of this kind, severe or slight, had occurred. The advantage mentioned might, perhaps, be less marked in English seams, which were renowned for the great strength of their roofs.

A vote of thanks was accorded to the author for his interesting paper.

Mr. H. W. G. HALBAUM read a paper upon "Mine-Ventilation: The Symmetric Relationship of Pressure, Velocity, and Conductive Area."

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE TECHNICAL COLLEGE, GLASGOW,
FEBRUARY 12TH, 1908.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, who had been duly nominated, were elected:—

MEMBERS—

Mr. SAMUEL BAILLIE, Penston Colliery, Tranent.
Mr. H. BRIGGS, Heriot Watt College, Edinburgh.
Mr. GEORGE S. CHRISTIE, Lanemark Colliery, New Cumnock.
Mr. DONALD JOHN M. DOWNIE, Rankinston, Ayr.
Mr. DAVID FLEMING, Maian Collieries Syndicate, Limited, Jamadoba Collieries, Jherria P.O., Bengal.
Mr. WILLIAM J. M'INTYRE, Glenboig Fireclay Mine, Glenboig.
Mr. HUGH WADDELL, Riggonhead Colliery, Tranent.

ASSOCIATE MEMBERS—

Mr. JOHN GEMMELL, 60, St. Enoch Square, Glasgow.
Mr. THOS. PATERSON NEILSON, Summerlee, Coatbridge.

Office-bearers for session 1908-1909 were nominated, and

[redacted]

DISCUSSION OF MR. JAMES BAIN'S PAPER ON "RESCUE-APPARATUS FOR USE IN MINES"* AND OF MR. H. A. FLEUSS' DEMONSTRATION OF HIS APPARATUS.

Mr. JAMES BAIN (Alloa) said that when they were investigating on behalf of the Fife, Kinross, and Clackmannan Coal-owners' Association, some fifteen or eighteen months ago, as to the various types of apparatus on the market, they had under consideration the apparatus that Mr. Fleuss had that night exhibited to them. They came to the conclusion that this apparatus, and that of Mr. W. E. Garforth,† were pretty much on similar lines. They appeared to be identical, but it was their opinion that Mr. Garforth's apparatus was better distributed, and that workmen would find it more advantageous for getting into narrow and low roads than with Mr. Fleuss'. They could not see that there was at the present time any material difference between the two apparatus, with the exception of the caustic soda that Mr. Fleuss used. He did not think there was any great advantage in that. It was, he thought, an important point to know the minimum thickness of seam that a person using this apparatus could travel in.

Mr. H. A. FLEUSS (London) said that he did not quite remember if fifteen or eighteen months ago the deputation which called had seen his old apparatus or his more modern design, such as was now before them. He might explain that on August 31st, 1907, there was a demonstration at Felling, near Newcastle-upon-Tyne, kindly arranged by Mr. C. B. Palmer, and at that demonstration the man wearing the Fleuss apparatus went under an obstacle quite 1½ inches less than the others. The man wearing his apparatus was not a miner, but a seafaring man, who had never been down a pit.

Mr. ROBERT MARTIN (Newmains) asked what depth his apparatus could go under a head of water, in order to rescue miners who might be there.

Mr. FLEUSS said that the greatest depth that he had gone under was 18 to 20 feet. He was not sure that this was the best type

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 72.

† "A New Apparatus for Rescue-work in Mines," by Mr. W. E. Garforth, *Trans. Inst. M. E.*, 1906, vol. xxxi., page 625.

of apparatus to use in water. It perhaps would be better to use the diving apparatus which he had specially prepared for that purpose.

Mr. ANDREW WATSON (Glasgow) asked the weight of the apparatus.

Mr. FLEUSS replied that it weighed 30 pounds.

The PRESIDENT (Dr. R. T. Moore) said that he supposed that this apparatus had been considered in connection with the rescue-station for Fife.

Mr. JAMES BAIN replied that the feeling of the committee was that Mr. Garforth's apparatus was simpler, and better adapted for use in mines. He had the impression, however, that the Fleuss apparatus had been greatly improved since he saw it last.

Mr. H. A. FLEUSS said that his apparatus had been greatly neglected. In the early eighties he had gone all over the country trying to introduce it to mining institutes; he had also gone down mines after explosions wearing the apparatus; but the subject did not at that time appeal to mining people. He had consequently abandoned the idea of introducing it into the mines. Lately, however, he had been struck with the remark of one colliery owner that the apparatus would justify its existence if it saved but one life. He had therefore once more given attention to his much-neglected apparatus.

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AN UNDERGROUND DIAMOND BORE AT PRESTON-LINKS COLLIERY.

BY RICHARD KIRKBY.

From the Crown pit of Prestonlinks colliery the Great seam is being worked beneath the Firth of Forth at a minimum depth of 360 feet down to nearly 600 feet. This seam is the top-most coal in the Edge Coal Series, and, as it was found necessary to prove the under seams, it was decided to put down a diamond bore underground at a point about 600 feet below low-water mark. The seam here dips due northwards at about 1 in 8.

A contract was made with a firm of mineral boring contractors to put down by hand a diamond bore. After considering the question, they decided to use motive power in preference to hand-labour; and, since there was no objection to the use of petrol, a petrol-engine was fitted to the ordinary boring gear.

The position of the bore was in the travelling-way, which runs parallel to the main haulage-dook, there being a 60 feet pillar between them. The travelling-road is the main intake, while the haulage-road is the return; and the bore was put down in the centre of the former just opposite a "througher" connecting the two. Advantage was taken of this road-end to draw the vertical carriage into it, when drawing the rods, and also as a direct road for the exhaust-pipe from the petrol-engine. The exhaust was led direct into a return air-current of about 13,000 cubic feet per minute, and it may be mentioned here that there was never the slightest inconvenience felt from the fumes.

A column of delivery-pipes from a three-throw pump runs up the travelling-road. The column was tapped for a water-supply, and two 40-gallon casks served as storage tanks in the event of a short stoppage of the pump. The amount of water used for the boring was from 10 to 15 gallons per minute.

The plant occupies little space. The road at the place was about 8 feet wide by 10 feet in height, and it was widened to 11 feet

for a length of about 9 feet. Advantage was taken of the narrow connecting-place to the extent of 5 feet in length. This made the place 16 feet wide at the bore. The roof was heightened and the pavement levelled 3 feet and 2 feet respectively, the total height being 15 feet just above the bore.

The "Wilson" type of diamond-drill plant, with which the bore was executed, consists of a 4 horsepower petrol-engine, vertical boring-carriage, ball-bearing boring-bar, and a double-acting Tangye pump, fitted with the usual water-hose connections (fig. 1). The rods were lifted with a hand-windlass.

plosion once in every two revolutions, immediately the piston has commenced its outward stroke. The accumulator has a pressure of 4 volts, and lasts for a week without re-charging. A petrol-tank was placed at the side and about 3 feet away from the engine, being connected to the carburetter by a small copper pipe. The carburetter is fixed to the cylinder-end.

The engine can be run at a uniform speed, and this is an important advantage when cutting coals, as their nature, whether hard or soft, can thereby be determined. The engine is able to drive the boring-bar at a speed of 150 revolutions per minute, a speed which is three times that attained by the hand-drill.

The consumption of petrol was not heavy, being about half-a-gallon per day up to 300 feet in depth, and from that quantity to one gallon per day at a depth of from 300 to 600 feet.

FIG. 2.—A $4\frac{3}{8}$-INCH CROWN, NIPPLE, AND TRAP-RING.

The boring vertical and the double-acting pump are driven from two belt-wheels on the crank-shaft, one on each side of the engine. The one being independent of the other, the belt can be thrown off the vertical and the pump kept going by itself.

The boring-bar used in this instance was $7\frac{1}{2}$ feet long, being half the length of the bar usually employed on a steam-plant aboveground. When the strata were suitable, 6 feet of cutting was done before it was necessary to disconnect the bar to add another rod. The contractors used a crown of their own design (fig. 2), which is much longer than the ordinary make. The advantage of this is that a deeper trap-ring can be employed, and this is less likely to get canted in the crown than the narrower rings. The crown was $2\frac{5}{8}$ inches in diameter, and the core produced was $1\frac{5}{8}$ inches in diameter. It would probably be found advantageous

to use a larger crown when motive power is adopted, and larger samples of coal would be got. The harder coals gave some good samples, but the softer seams did not turn out so well. The writer understands that the same motor is at present driving a crown $4\frac{3}{8}$ inches in diameter, giving a core $3\frac{1}{8}$ inches in diameter, so that the plant can give a very fair size of core when required.

The depth of the bore was 601 feet, and the work occupied 113 days. This compares very well with a chisel-bore from the surface, 432 feet deep, which took 156 days to complete. In this chisel-bore were three kingle stones, 12 feet in all, which alone took 46 days to bore through. It took fifty chisels to cut 2 feet of one kingle-bed. Some kingle-beds were also encountered in the diamond bore, but gave no trouble. One disadvantage of the underground bore was that, owing to the head-room being only 15 feet, each rod had to be disconnected, whereas at the surface three or four rods may be put on at once.

In this diamond bore the various operations proceeded without a hitch until the completion of the bore. The bore was afterwards plugged up, so as to stop the flow of water, which, however, was not very heavy.

The writer understands that this bore in the Crown pit is the first case in the history of mineral-prospecting in Scotland in which a petrol-engine has been successfully used for driving a diamond-drill plant. Of course, it is not suggested that this

[redacted]

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JANUARY 14TH, 1908.

MR. JOHN ASHWORTH, PRESIDENT, IN THE CHAIR.

The following members were elected, having been previously nominated:—

MEMBERS—

Mr. EDWARD T. DAVIES, Colliery Manager, Wynnstay Colliery, Ruabon, North Wales.

Mr. A. GHOSE, Mining Engineer, 42, Shambazar Street, Calcutta, India.

Mr. GEORGE BOOKER HACKETT, Mining Engineer, P.O. Box 3117, Johannesburg, Transvaal.

STUDENTS—

Mr. GEORGE BENNETT ECCLESHALL, 34, Bradford Terrace, Worsley Road, Farnworth, near Manchester.

Mr. THOMAS EMRYS EVANS, 5, Kelnerdeyne Terrace, Rochdale.

Mr. EDWARD FIELDEN PILKINGTON, The Headlands, Prestwich, Manchester.

DISCUSSION OF MR. W. H. COLEMAN'S PAPER ON "BYE-PRODUCTS FROM COKE-OVENS,"* OF MR. W. B. M. JACKSON'S PAPER ON "A BYE-PRODUCT COKING-PLANT AT CLAY CROSS,"† AND OF MR. A. VICTOR KOCHS' "NOTES ON BYE-PRODUCT COKE-OVENS, WITH SPECIAL REFERENCE TO THE KOPPERS OVEN."‡

Mr. CHARLES PILKINGTON (Manchester) said that he felt that those who were colliery proprietors ought to be able to discuss these papers, and he was rather ashamed that he knew so little of the subject. He thought that they would all have to go thoroughly into this question, if they were to make the coal-trade pay in the future, when it became more expensive to get coal;

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 331; and *Trans. M. G. M. S.*, vol. xxx., page 197.

† *Ibid.*, 1907, vol. xxxiii., page 386. ‡ *Ibid.*, page 398.

and he hoped that, in three or four years' time, if this question came up again, they would be able to say something about it, or, at all events, that the younger members would.

The PRESIDENT (Mr. John Ashworth) called attention to the Armstrong vertical bye-product coke-oven, and explained that this oven was constructed on a totally different plan from that adopted generally in the construction of bye-product ovens. Its vertical construction admitted of considerable pressure during the coking period, and its circular form allowed of a larger output than was possible with the horizontal ovens; it was also cheaper in construction. It was efficient in the utilization of the heat generated in the combustion-flues—as might be gauged from the fact that, although the oven was internally very hot, the outside brickwork remained just sensibly warm to the hand.

The strong pressure brought to bear upon the coal in the vertical oven produced denser coke, and the heavy hydrocarbons from the escaping gas passed through the coke above, the result being that a very fine coke, free from gas, was produced. The attention required to be bestowed upon this vertical oven was, he understood, less than was necessary in the case of horizontal ovens; and, in fact, he (Mr. Ashworth) considered that it possessed quite a number of advantages over existing types.

A report upon the new oven had been prepared by Mr. W. Carrick-Anderson, in the course of which that gentleman stated that—

[redacted]

	Tons.	Cwts.
Coke drawn from oven on November 15th, at 10·30 a.m., weighed in waggon ...	3	13·00
Specimens additional ...	0	0·75
Total weight ...	3	13·75
Deduct moisture, 0·62 per cent. ...	0	0·50
Net dry coke ...	3	13·25

Dry coke drawn = 80·9 per cent. of air-dry coal.
Laboratory results = 71·92 „ „ „

ANALYSIS OF COAL.

	Air-dry. Per Cent.	Moist as charged. Per Cent.
Volatile matters :		
Gas, tar, etc. ...	27·09	25·52
Water ...	0·99	6·73
Coke :		
Fixed carbon ...	66·78	62·91
Ash ...	5·14	4·84
Totals ...	100·00	100·00

	Per Cent.	Per Cent.
Total sulphur ...	0·928	0·874
Caking index ...	—	18
Coke ...	—	Swollen and bright.
Ash ...	—	Reddish-white.

ANALYSIS OF COKE.

	Per Cent.
Moisture ...	0·62
Gas and tar ...	1·37
Sulphur ...	0·776

November 27th, 1907.

W. CARRICK-ANDERSON.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
FEBRUARY 11TH, 1908.

MR. JOHN ASHWORTH, PRESIDENT, IN THE CHAIR.

DISCUSSION OF MR. DAVID M. S. WATSON'S PAPER ON "THE FORMATION OF COAL-BALLS IN THE COAL-MEASURES."*

Mr. JOSEPH DICKINSON (Pendleton) said that the paper described properly the Upper-foot coal-seam and its junction with the Gannister coal-seam near Bacup, forming northwards one seam known as the "Mountain Four-foot." It further described certain peculiar accompaniments, notably that "coal-balls occur in at least two other coal-seams in Lancashire," one of them at Stalybridge, the other near Laneshaw Bridge, about two miles north-east of Colne, probably in the Second Grit. Both of [redacted]

were found in other parts of the coal-field, both above and below, but not with the peculiarly complete series of calcareous and ferruginous concretions, nor with the same mine-water, which possessed the property of turning a person's skin brown as if with nitric acid.

It was unfortunate that the error had been made in the paper, and he should like the correction to be made in the *Transactions*.

Mr. WILLIAM WATTS (Wilmslow, near Manchester) said that the thanks of the members were due to Mr. Dickinson for his remarks, which were simply an explanation of where coal-balls had been found, apart from the places mentioned in Mr. Watson's paper. Mr. Dickinson wished to give a wider area for the location of these particular nodules or balls.

Many years ago he (Mr. Watts) had found a coal-ball in one of the lower coal-seams, under Gorse Hall, Stalybridge, which had the appearance of a round-headed hammer at both ends, and was composed internally of gritty material with an external film of carbonaceous matter. Both ends were practically equal in size, and evenly narrowed down in the middle.

Mr. JOHN MCARTHUR JOHNSTON read the following paper on "Stirling and other Water-tube Boilers as applied to Collieries and Coking-plant":—

STIRLING AND OTHER WATER-TUBE BOILERS AS APPLIED TO COLLIERIES AND COKING-PLANT.

By JOHN McARTHUR JOHNSTON.

The writer does not propose to deal with the historical aspect of the water-tube boiler, but to confine himself to the modern water-tube boiler, and the results obtained from its use within recent years.

The success which attended well-designed water-tube boilers led to the invention and production of a large variety of boilers of this type, some of which were possessed of useful and desirable features. Three of the best known water-tube boilers are the Babcock and Wilcox (fig. 3), the Stirling (figs. 4, 5 and 6), and the Climax; the first-mentioned having straight tubes, with which the members no doubt are familiar, the Stirling slightly bent tubes, and the Climax curved tubes.

The Climax (or Morrin) boiler consists of a vertical drum, into which are expanded a large number of loop-like tubes. These tubes extend practically from top to bottom of the drum, and form the chief portion of the heating-surface. A firebrick-

[redacted]

against those of the cylindrical or internally-fired type will serve to illustrate the advantages to be obtained by using boilers of the water-tube type.

Lancashire, Cornish, egg-ended, and other externally-fired boilers, have for many years been in extensive use for steam generation in iron- and steel-works, coal- and iron-mines; but,

FIG. 1.—WATER-TURBINE TUBE-CLEANER.

FIG. 2.—CHAIN-SCRAPER TUBE-CLEANER.

with the march of progress, water-tube boilers have in recent years been installed in a large number of such works. The increasing number of boilers, of the water-tube type, which have been put down at iron-works and mines have testified to the advantage which they have over the older type of boiler, and call for more serious consideration than they have usually received

from those who have hitherto shunned them as being doubtful or troublesome. The experimental stage has long since been left behind, and hundreds of steam users are now convinced that they have made a big step forward by installing water-tube boilers when extensions of plant had to be considered.

The writer would refer to Mr. Bryan Donkin's work on "The Heat Efficiency of Steam Boilers,"* which is valuable as containing a record of 400 carefully made boiler-tests under various conditions. This book contains a large number of tests for each type of boiler, and shows the average results as representing fairly well the efficiency of the different types of boilers.

The latest edition of this book is dated 1898, and although the cylindrical type of boiler has been improved very little since the book was compiled, the water-tube boiler has made very considerable advancement, in numbers, in detail, and in design.

Of the 107 tests of Lancashire boilers recorded in this book, the efficiency averaged 62·4 per cent. Unfortunately, Mr. Donkin does not give an equal number of tests of the water-tube boilers; but at the head of the list were shown water-tube boilers with an efficiency of 77·4 per cent.

In comparing the Lancashire boiler with a properly designed water-tube boiler, it is safe to say that the efficiency of the latter represents a saving in coal of about 15 per cent. Without a careful study of all the causes and effects that lead to this result, the statement appears to be rather a startling one; nevertheless, [redacted]

very important feature of the externally-fired water-tube boiler being that the combustion-chamber is enclosed on three sides by firebrick walls, the initial temperature in the combustion-chamber is consequently maintained at a very high rate, which ensures practically complete combustion before the gases come into contact with the heating surfaces of the boiler. The temperature in the combustion-chamber is, therefore, much higher than in the internally-fired boiler, in which the fire is surrounded by the cooling surfaces of the boiler. On the grate of the firebrick-lined furnace, very low-class fuel can be burned with high efficiency, a point of very great importance, as will be seen from the figures given below, which are taken from actual practice.

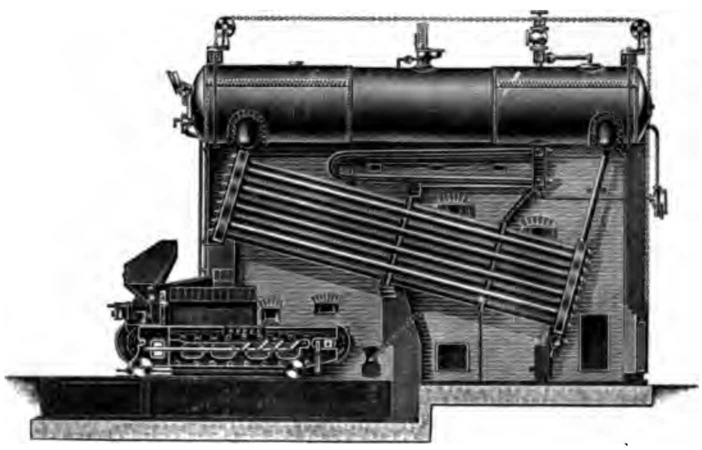

FIG. 3.—BABCOCK AND WILCOX WATER-TUBE BOILER.

In a works with economical mill-engines of 500 indicated horsepower, and Lancashire boilers, coal costing 12s. per ton was used, with a consumption of 2 pounds per indicated horsepower, which amounted to £2 8s. 3d. per day, or £723 per year of 300 working days.

Water-tube boilers were substituted, with special grates for burning "gum" or "smudge" costing 4s. per ton. The consumption of this fuel was $2\frac{1}{2}$ pounds per indicated horsepower, the cost per day of 10 hours being £1 2s., or £330 per annum, showing a saving of over 50 per cent. for the same amount of steam produced. Naturally, to burn fuel of this class ample boiler-power is required, but the increase in capital expenditure would be in a very short time repaid by the saving in running-costs.

Choice of Boiler.—The choice of a boiler is a business proposition, and sentiment should not be allowed to enter into it. The purchaser naturally takes into account the business aspect of the transaction, and the following points require due consideration:—(1) Safety, (2) cost of maintenance, (3) cost of cleaning, (4) fuel economy, and (5) first cost. The author has placed these points in the order named, that being the order of their importance in the minds of most users.

In choosing a boiler the steam user would probably ask: "What steam-generator will earn the most money, at the least cost of coal and maintenance?" The Lancashire boiler, which is a popular and well-tried steam-generator, is probably better known than any other form of boiler. Generally speaking, when new plant is under consideration, it becomes a simple matter to fix the number of Lancashire boilers required; but it is equally wellknown that this type of boiler has also its faults, and it may be assumed that its defects have come to be taken as a part of the boiler itself, and therefore, owing to custom, do not receive any serious consideration when making choice of the boiler to be installed.

It is often stated in favour of the Lancashire boiler that all of the internal surfaces are accessible for cleaning and examination, that it has a large volume of water, and large steam space; but it also has a small ratio of heating-surface to grate-area, the ratio being about 25 to 1; consequently the gases pass away [redacted]

rarely bought or sold to work at a low rate of evaporation, the tendency rather being to overload the boiler: consequently, the gases leave the boiler at a high temperature, which has the effect of reducing the efficiency to about 50 per cent.

In the event of overheating of the furnace-tube of the cylindrical type of boiler, due to excessive scale, or shortness of water,

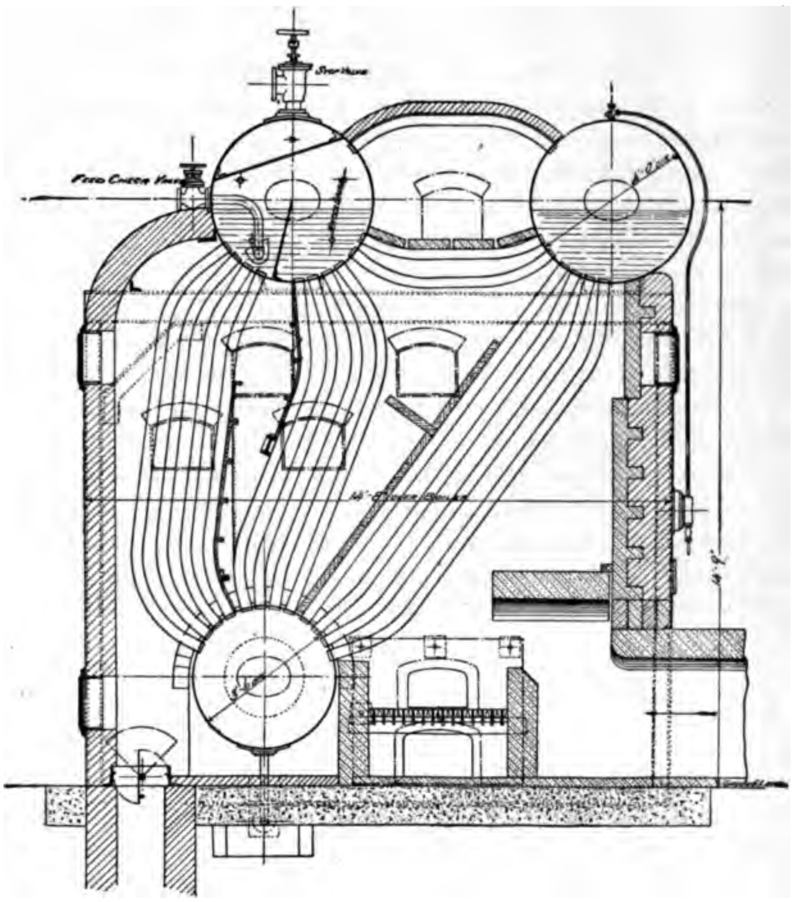

FIG. 4.—THREE-DRUM TYPE OF STIRLING WATER-TUBE BOILER.

from neglect, the tube becomes red-hot and pliable; and, being unable to withstand the pressure, it collapses, and probably ruptures, with serious results. The boiler is then necessarily laid off for a considerable time for repairs, which moreover necessitate the services of a skilled boilermaker.

One special feature of the water-tube boiler is safety, and

should a rupture in a tube occur, it is purely local in its action, and only a limited amount of water and steam contained in the tube can immediately escape, and consequently, no serious damage to property occurs; while in the cylindrical boiler there is a large volume of water, which, if suddenly released, might cause serious loss of life and damage to property.

If ever a Lancashire boiler, 30 by 8 feet, working at, say, 160 pounds per square inch (the usual pressure nowadays), were to rupture in the shell, terrible wreckage and loss of life might occur. How disastrous Lancashire boiler explosions have been, and might be, is wellknown, and may be illustrated by the fact that some years ago a Lancashire boiler, 7 feet in diameter, and working under a pressure of 80 pounds per square inch, exploded at Batley (Yorkshire), causing the loss of 23 lives, and doing immense damage.

In the cylindrical type of boiler the ratio of heating-surface to grate-area is practically a fixed quantity: the grate may be lengthened, though not increased in width; but in a water-tube boiler the ratio can be varied at will, to obtain the best economy from the different classes of fuel.

In the event of repairs being necessary in a boiler of the water-tube type, the works' mechanics, not necessarily skilled men, can do all that is required. At the worst, supposing that a tube becomes split, or bulged, through scale or neglect in other ways, such as oil being allowed to come into contact with the [redacted]

(freshly fed) are cooled on the furnace-plates, and consequently perfect combustion is not attainable, and black smoke issues from the chimney. The above remarks apply especially when the boiler is working under forced conditions. With hand-firing much excess air passes through the thin places in the fire, and

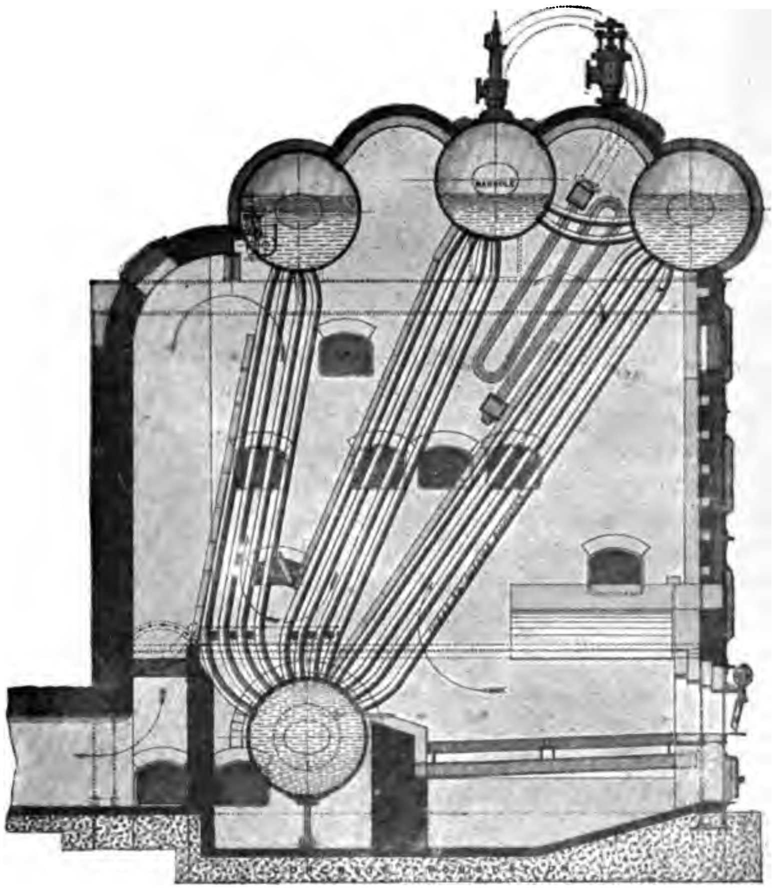

FIG. 5.—FOUR-DRUM TYPE OF STIRLING WATER-TUBE BOILER.

complete mixture of the gases does not take place. Unless a proper mixture of the gases takes place, the efficiency must be low.

The design of the water-tube boiler exhibited before the members permits of a very spacious combustion-chamber,

which, as before mentioned, is lined with firebrick, with a firebrick arch immediately over the fire; this arch becomes white-hot, and serves various useful purposes, namely, assisting the ignition of the freshly-fed fuel, igniting the gases (requiring a high temperature), also heating the air which rushes in when the firing door is opened, and thus preventing any of the deleterious effects resulting from the sudden impingement of cold air on the heating-surfaces. It will be readily admitted that the firebrick arch is entitled to special attention, and that it is a most useful factor in the economy of the water-tube boiler; being maintained at a great heat, it ensures practically perfect combustion, as the gases are completely consumed before they come into contact with the heating-surfaces of the boiler.

It is admitted that perfect combustion can only take place in a properly-designed firebrick-lined furnace. It is also well-known that no type of boiler attains perfection in its work, but reason dictates that we may safely choose the boiler which most closely approaches perfection.

In modern practice, it is desirable to work with high-pressure steam-engines, which necessitates boilers capable of supplying a fixed quantity of high-pressure steam economically. In such a case the cylindrical type of steam-generator is required to be built of plates of great thickness, in order to withstand the high pressure, and thus the initial cost is considerably increased.

The writer would mention that he has selected the Stirling [redacted]

Course of Gases.—The gases, after leaving the region of the grate and arch, travel up the first bank of tubes, guided by a baffle-wall, cross over to the second bank of tubes, and travel a downward path to the bottom of the second baffle-wall, thence crossing to the third bank of tubes, along which they are made to pass upwards and to the chimney.

Course of Water.—The feed-water enters at the rear drum, and flows down the rear bank of tubes to the mud-drum; during

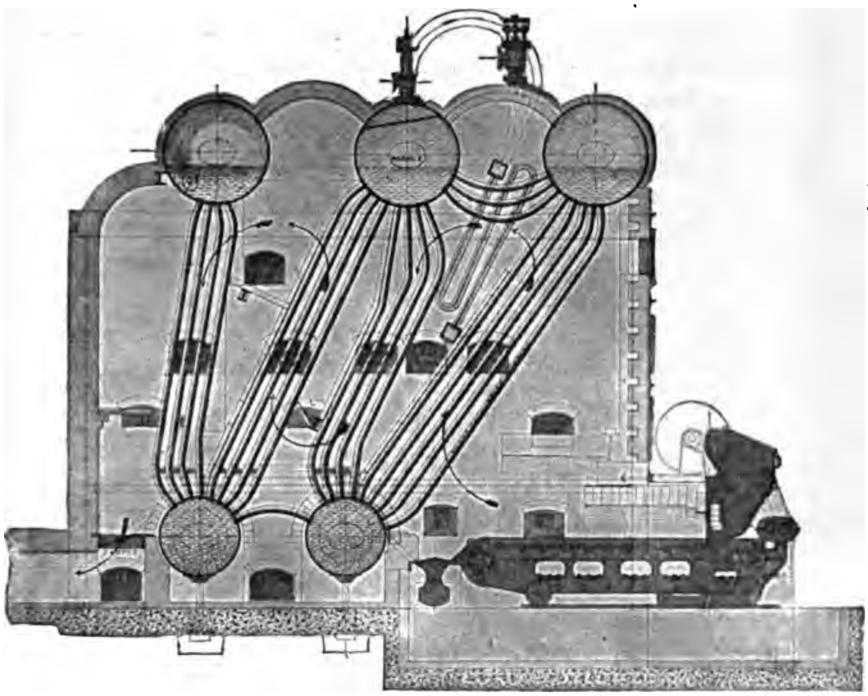

FIG. 6.—FIVE-DRUM TYPE OF STIRLING WATER-TUBE BOILER.

this passage sufficient heat is taken up by the water to render insoluble any lime-salts contained therein, which with the mud are deposited in the bottom drum. From the bottom drum the water and steam rush up the front bank of tubes to the front drum, from which the water then flows to the central drum, and thence downwards to the mud-drum, thus creating a flow in a circular tour at a rapid rate.

Economy and Circulation.—Theoretically, one pound of fuel of a known heat value is capable of evaporating a certain fixed

quantity of water, but, in practice, the theoretical evaporation is never reached, for obvious reasons; and it follows that the most efficient boiler is that which will absorb or utilize the most heat from the fuel. This, expressed as a percentage of the theoretical amount, varies with different types of boilers from 40 to over 80 per cent.

Rapid circulation is a potent factor in the economy of heat-transmission from the furnace gases to the water in the boiler, the evaporation depending on the difference in temperatures between the furnace gases and the water in the boiler; the greater the difference between the two temperatures, the more heat is transmitted through the plate; consequently more heat is absorbed by the water, and more water is evaporated. When the circulation is sluggish, the bubbles of steam adhere too long to the plate, the difference of temperature is less, and evaporation is slow. By increasing the circulation, more heat is transmitted, as the water and steam do not remain so long in contact with the metal; economy is therefore obtained by increasing the circulation, an advantage that the water-tube boiler has over the cylindrical type of boiler, in which, as is well known, the circulation is bad.

Safety.—Returning to the design and construction of the Stirling boiler, the writer would point out that as all the surfaces are either cylindrical or spherical, no stays are required. No castings are employed, and the whole arrangement is practically

[redacted]

cost approximately £3,500, including economizer. The net saving in capital outlay would be £1,000, and in addition there would be a saving of at least 50 per cent. on the expenditure in steam and feed-piping. Estimating the cost of coal at 10s. per ton for a period of 50 weeks of 60 hours each, the saving per annum would represent 24 per cent. on the capital outlay. The saving in fuel, capital expenditure, piping, and rates and taxes for floor space, would represent a considerable one over the Lancashire type of boiler.

FIG. 7.—STIRLING BOILER FED BY BLAST-FURNACE GAS.

Feed-water.—The writer is of opinion that all feed-water to boilers should be free from matter which might be deposited inside; but in many cases this state of affairs cannot readily be obtained. Very many Lancashire boilers are seldom, if ever, properly scaled, because of the long time necessarily occupied in the operation. For removing scale from the tubes of water-tube boilers, the author exhibits two sets of apparatus. One is a simple mechanical apparatus by which the internal surfaces can be cleaned in a very short time and at a small outlay (fig. 1). It consists of a small water-turbine connected to cutters and chippers, operated by water-pressure of about 100 pounds per

square inch. The bends in the tubes present no obstacle to this machine. The second device (fig. 2) is a scraper for removing comparatively soft scale, and drawn through the tubes by means of a chain. The difficulty of cleaning water-tube boilers is often a point urged against this class of boiler, but only by those without experience of them, or by those who have handled some of the earlier types of water-tube boilers; but there is no reason why this simple mechanical contrivance should not clean quickly and thoroughly all the internal surfaces. The turbine should be connected by a 1½-inch hose-pipe to the feed-pumps or water-mains, and entered at the top ends of the tubes. The turbine, rotating at a high speed, causes the arms to fly out and round, so that the cutters remove the scale which is washed down in advance of the turbine into the bottom drum, whence it can be easily removed by hand.

Water-tube boilers can be designed to work at high pressures with very moderate thickness of plates and tubes, also in very large units, up to 40,000 pounds evaporation in one boiler. This involves only one set of mountings, piping, etc., and occupies correspondingly less space than a number of cylindrical boilers to give a like duty. Another feature which may be noted is that cylindrical boilers, with their attendant economizer (an early form of water-tube boiler), require the services of more men than one large water-tube boiler, and running costs are therefore higher.

The first cost of a water-tube installation is lower, the attend- [redacted]

The hot gases, on entering a water-tube boiler, become split up into a large number of small streams, and the thin metal of the tubes permits of rapid transmission of the heat to the water; and, as the rapid circulation prevents the steam-bubbles from remaining any length of time on the heating-surfaces, the efficiency is maintained at a high rate. It will be seen on reference to figs. 4, 5 and 6, that the gases enter at the bottom of the front bank of tubes. An ordinary firegrate is fitted for hand-firing, for use when the ovens are shut off.

Assuming the average amount of water evaporated in a Lancashire boiler per pound of coal coked at from 1 to 1·4 pounds, the average in a water-tube boiler is about 1·3 to 1·7 pounds, being an increase of about 30 per cent.

The mean evaporation over a four days' test of a water-tube boiler fired by waste-heat from coke-ovens (as shown below) was 1·7 pounds of water for each pound of coal coked. The temperature of the gases leaving the ovens was 2,000° Fahr., and the temperature of the gases entering the boiler 1,700° Fahr.; the boiler-inlet was 29 feet from the coke-ovens, and, in consequence, there were large radiation-losses in the flue.

The following is a comparison of the work of one water-tube boiler with that of two Lancashire boilers under similar conditions, at the Victoria Garesfield colliery, Rowlands Gill, near Newcastle-upon-Tyne:—

	Stirling Boiler.	Lancashire Boiler.
Description of boilers	1 No. 12, Class A ...	2 of 28 by 8 feet.
Number of coke-ovens	22	37
Heating-surface	1,611 square feet ...	1,796 square feet.
Water evaporated from and at 212° Fahr. per pound of coal coked	1·7 pounds	1·33 pounds.
Temperature of gas entering boiler	1,720° Fahr.	1,700° Fahr.

Owing to reasons before mentioned, the water-tube boiler has the advantage of being able to abstract more of the heat from the gases than the cylindrical boiler.

In 1907, a test was made over a period extending from May 21st to 28th, at Chopwell colliery, County Durham, on a water-tube boiler fired by waste-gases from coke-ovens, and the following results were obtained:—

Duration of test		168 hours.
Heating-surface of boiler		4,170 square feet.
Coke-ovens (beehive)	per oven	134·5 square feet.

Form of furnace :	47 coke-ovens gas-fired.
Heating-surface of superheater	295 square feet.
Average boiler-pressure by gauge	157·4 pounds.
,, temperature of steam at the above pressure	370° Fahr.
,, ,, of superheated steam	476·2° Fahr.
,, amount of superheat	106·2° Fahr.
,, temperature of feed-water entering the boiler	61° Fahr.
,, ,, of flue-gases leaving the boiler	500° Fahr.
,, ,, of gases entering the furnace	2,228·1° Fahr.
,, ,, of the external air	50° Fahr.
Total quantity of coal as fired	1,389,696 pounds.
Quantity of coal as fired per hour	8,272 pounds.
Draught	0·5 inch.
Total weight of feed-water to boiler (actual)	2,136,700 pounds.
Equivalent water evaporated from and at 212° Fahr.	2,734,976 pounds.
Factor of evaporation	1·28.
Water evaporated per hour	12,718·4 pounds.
Equivalent evaporation per hour, from and at 212° Fahr.	16,279·5 pounds.
Evaporation under actual conditions per pound of coal carbonized	1·537 pounds.
Equivalent evaporation from and at 212° Fahr. per pound of coal carbonized	1·968 pounds.

Blast-furnaces.—Water-tube boilers have also been fired by blast-furnace gas (fig. 7). The gas enters at a point immediately under the incandescent arch, the arch being dropped at the back to ensure better mixture of the air and gas. Any accumulation of dust can easily be removed by means of the steam-jet applied through the cleaning-doors, without shutting down the boiler.

Explosion-doors are sometimes fitted to relieve the brick- [redacted]

was working at 50 pounds per square inch the evaporation was 9·4 per cent. higher in the water-tube boiler than in the Lancashire boiler. When working at 110 pounds per square inch, the evaporation of water per pound of coal in the water-tube boiler was 11 per cent. higher than in the Lancashire boiler.

Coal-refuse.—When designing steam-plant for a new colliery, it would be advisable to bear in mind the ability of a water-tube boiler to burn and generate steam from the unsaleable materials taken out of the pits. In a properly-designed grate of a water-tube boiler, almost any refuse from coal-mines can be used, including old pit-props, other damaged and rejected timber and road-sweepings, and quite a noticeable saving can be effected.

In conclusion, the writer trusts that he has been successful in showing the advantages which may be claimed for the water-tube boiler over the older type, also that a boiler with these advantages can be designed possessing great safety with simplicity of construction, and an economy unrivalled by that of any other type of stationary boiler.

Mr. G. B. Harrison (H.M. Inspector of Mines, Swinton) moved a vote of thanks to Mr. Johnston for his paper.

Mr. Charles Pilkington (Manchester), in seconding the motion, asked whether the use of the chain-stoker did not cause a great loss of fuel. He knew that such was the case in many instances. With regard to the method of cleaning the tubes, it seemed to him that the wearing process might be very severe.

Mr. J. McArthur Johnston (Manchester), in acknowledging the vote of thanks, said that with regard to the chain-grate his experience showed that fuel was saved and not lost by its use. The coal was, by its use, laid in more regularly, and used more economically than could be done by hand-firing, and any coal that fell between the bars could be recovered. He was also of opinion that a much better mixture of the gases was obtained in this way than was possible by hand-firing. With regard to the

method of cleaning, the wear of the tubes by this process was slight and negligible; indeed, the methods of chipping and cleaning a Lancashire boiler were more destructive, in his opinion, than those in use for cleaning the tubes of a Stirling water-tube boiler.

The further discussion of the paper was adjourned.

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THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
FEBRUARY 3RD, 1908.

MR. G. P. HYSLOP, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

STUDENTS—
Mr. W. M. CARTWRIGHT, Sneyd Colliery, Burslem, Stoke-upon-Trent.
Mr. J. R. HARRISON, Trent Vale, Stoke-upon-Trent.
Mr. T. G. KENT, Sneyd Colliery, Burslem, Stoke-upon-Trent.

TATE'S IMPROVEMENT FOR SAFETY-LAMPS.*

Mr. A. M. HENSHAW (Talke) exhibited and described a new gauze-indicator for safety-lamps, the invention of Mr. J. W. Tate, one of his old pupils. The device appeared to him (Mr. Henshaw) to fulfil perfectly the object in view, namely, to prevent the possibility of a lamp being put together and taken into the pit without the gauzes having first been inserted.

Mr. W. G. PEASEGOOD read the following paper on a "Discharge of Inflammable Oil in a Coal-seam":—

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 321.

DISCHARGE OF INFLAMMABLE OIL IN A COAL-SEAM.

By W. G. PEASEGOOD.

It may be interesting to the members of the Institute to examine a sample of oil taken from the floor of the Bullhurst seam of the Fair Lady pit, Leycett collieries. The section of this seam is as follows:—

	Feet.	Inches.	Feet.	Inches.
Metals			12	8
Coal			0	11
Rock			7	6
Bullhurst coal-seam:				
Tops	3	4		
Middles	1	10		
Wall coal	5	1		
			10	3
Hussle			0	6
Warrent			2	3
Rock	about		15	0

About 200 acres of this coal have been worked at the above collieries, and oil has not been perceived before in the Bullhurst

[redacted]

	Per cent.	Per cent.
Combustible :		
Volatile matter	10·40	
Fixed carbon	2·85	
		13·25
Non-combustible :		
Ash (mineral matter)		86·75
Total		100·00

At the end of May, when getting ground out for a preparatory gob-fire stopping on the same level, but 90 feet out-bye from the place where the moist hussle was found, a quantity of oil

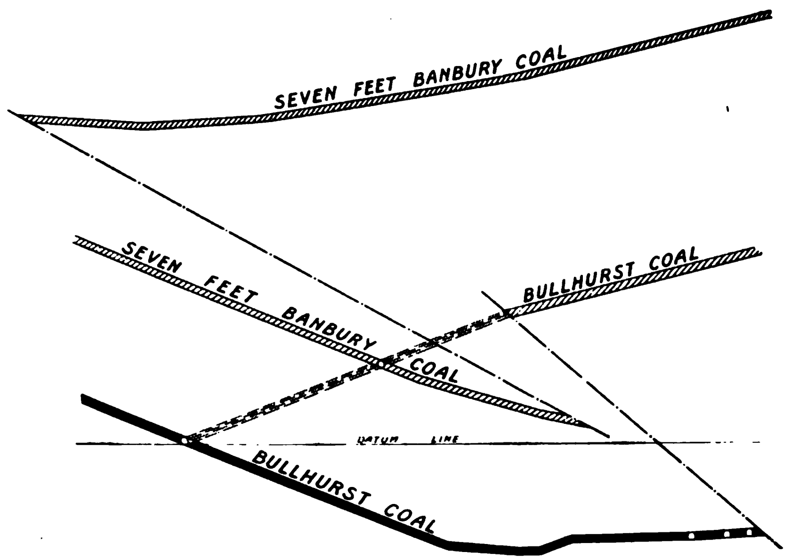

FIG. 1.—SECTION ON LINE A-B (FIG. 2) OF DISTRICT IN BULLHURST COAL-SEAM WHERE OIL WAS FOUND.
SCALE : 225 FEET TO 1 INCH.

and water was discovered in the floor, about 2 feet from the foot of the seam, which gave off a very much stronger smell of petroleum. This oil and water came from a break in the floor, and was frequently emptied ; but it kept at one level for two or three days, and then practically disappeared. Figs. 1 and 2 are a section and plan respectively of the district where the oil was found.

By personal experiment the oil was proved to be highly inflammable, and when cooled to about 65° Fahr. it solidified to the consistency of ordinary tub-grease. When found in the pit,

its consistency was about that of paraffin. The temperature in this district was 88° Fahr., 66° Fahr. being the temperature on the surface.

The writer is indebted to Messrs. Gaunt and Hickman, of Wolverhampton, for the following analysis:—

Colour	Dark green
Consistency	Solid
Specific gravity at 60° Fahr.	0·840 to 0·838
Boiling-point	206·6° Fahr. (97° Cent.)
Close-test flash-point	122° to 124° Fahr.
Iodine number	4·2 per cent.
Free organic acid (calculated as oleic)	0·07 per cent.
Mineral acid	*Nil*
Water	2·0 per cent.
Grit and suspended matter	Traces
Viscosity (Redwood's viscometer)	100° Fahr., 55 seconds; 120° Fahr., 43¾ seconds; 140° Fahr., 39 seconds.

The sample of oil was distilled, and, although the amount was too small to allow of a trial with steam, still, some valuable results were obtained, as follows:—Petrol, about 4 per cent.; petroleum of good flash-point, 7 to 10 per cent.; heavy burning oil, 15 per cent.; and light mineral oil, 17 per cent. The residuum was solid, and of a stiff consistency, harder than butter. There is some amount of paraffin-scale in the oil, probably 5 per cent. The increase in viscosity, after removal of the light oils, was very marked in the case of this residuum. The specific gravity at 60° Fahr. was 0·875; and the viscosity of the residuum (Red-

[redacted]

The residuum from the Madeley oil would be unsuitable for use except as a grease, unless the paraffins were removed first of all. This would require further experiments and further quantities of the crude oil. It is difficult to say what could be done with this oil, as the quantity given was far too small for proper analysis. Better results could possibly be obtained by varying the method, and by familiarity with the conditions. If obtained in sufficient quantity, the oil would no doubt be valuable, and would probably bring about £2 10s. per ton.

The water present with the oil is heavily loaded with sodium-chloride.

It would be interesting to know whether any similar oil has been found in any other colliery in North Staffordshire. Crude petroleum has been found in the neighbourhood of a whin-dyke intersecting the Oil-shale Measures in Scotland. Many years ago, crude petroleum was found in the sandstone beds in the Shropshine coal-field; the miners collected it, and it was sold by a chemist and druggist as "Betton's British oil." Petroleum has also been obtained in the Deep Main pit of the Riddings colliery, Alfreton, and in large amounts at Southgate colliery, near Chesterfield, from the roof of the Top Hard seam; the maximum yield from this latter source amounted to 66 tons per annum in 1887, and to 35 tons in 1890.

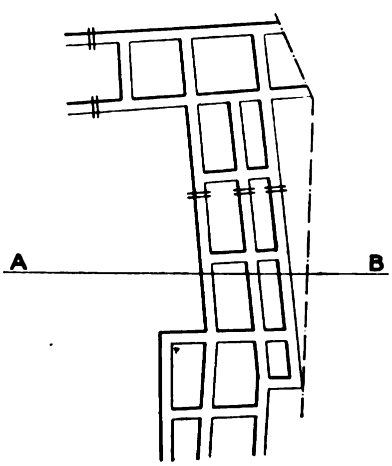

FIG. 2.—PLAN OF DISTRICT IN BULLHURST COAL-SEAM WHERE OIL WAS FOUND.
SCALE: 180 FEET TO 1 INCH.

Mr. JOHN CADMAN (H. M. Inspector of Mines, Newcastle-under-Lyme) said that the presence of petroleum associated with coal-seams, as in the case described by the author, was of special importance to those interested in oil-mining. For the last few years he had been intimately connected with the exploration of oil-fields in the colonies, and he was particularly struck with the

many and varied theories advanced to account for the origin of petroleum. He thought that the facts recorded in the paper were excellent evidence in support of the organic theory, which suggested vegetable remains as the point of origin. The occurrence of oil, in close proximity to beds of coal, was by no means uncommon; but, so far as he was aware, it was seldom found in any great quantity. He hoped that Mr. Peasegood's case would prove an exception, and that he would be able to take advantage of such a valuable mineral. He would refer anyone interested in the subject to a paper by Mr. A. A. Hall,* which described an oil similar to the one discovered by Mr. Peasegood, and which he (Mr. Cadman) had collected at Longton, North Staffordshire, many years ago.

He had great pleasure in proposing a vote of thanks to Mr. Peasegood for his excellent record.

The vote was seconded and carried.

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MEMOIR OF THE LATE JOHN WARD.

By JOHN T. STOBBS.

It is only fitting that some notice should appear in our *Transactions* of the life and work of one who has done so much to make the North Staffordshire coal-field famous on account of its palæontological treasures, most of which were unearthed by him; of one, moreover, who was in the best sense a typical North Staffordshire man, and who, having been born, reared, and educated in the district, lived the whole of his days within a few miles of his birthplace. His speech, naturally, bore the local accent; he entered fully into the life of his surroundings, and devoted a liberal share of his time to the municipal affairs of his town. His skill and knowledge as a scientific man were acquired, and his main life-work accomplished, within a very short distance of the place where we meet to-day. This work was so intimately connected with the industry of coal-mining, and is of such permanent value, particularly to this district, that it is due to succeeding generations, no less than to the memory of Mr. Ward, that some summary of his career should be given to this Institute, since, as Dr. Johnson says, "all excellence has a right to be recorded," and seldom has North Staffordshire produced such a man as the subject of this memoir.

John Ward was born at Fenton on August 11th, 1837. As a boy, he attended Dr. Haslam's Ivy House school, Hanley, but it cannot be said that anything that he learned there gave a stimulus to, or otherwise nurtured, those scientific tendencies which, eventually, developed into master-motives with him. He was essentially a self-taught man, so that his youthful days were never darkened by preparation for examinations. He unquestionably gleaned much from intercourse, by letter or in person, with co-workers, for which he as certainly gave *quid pro quo*. Nothing can be more instructive than to trace the gradual unfolding of his abilities as a scientific worker, because, viewed from the outside, it seems to have been left so much to personal inclination

and mere chance. The lives of such men are the despair of orthodox educationists, for machinery, educational or other, can never produce them. Unremitting work, and work only, developed his powers. We learn that in his teens he was given to fossil-hunting—and as yet it was simply "hunting"—on the spoil-heaps of collieries in the Fenton and Longton area, and the interest thus awakened, and strengthened by discoveries which touched his imagination, set the seal to his life-work.

It is worth emphasizing that he had already learned to carry on this fossil-hunting alone, as this, at once, denotes character in the youth, and such tasks as he had, perchance unwittingly, entered upon, Kipling tells us, are "always one man's work—always and everywhere." This, then, was an important acquisition, and associated with it, we may observe the order in which his interest in geology developed; he began by obtaining specimens of his own, and as he handled these he could not help desiring to know everything possible pertaining to them; then books became a necessity, and the science ever remained for him an attraction and source of delight.

He was engaged in the offices of Golden Hill colliery, Foley, near Longton, belonging to Messrs. J. H. Goddard and Company, when they worked the Deep Mine, Chalkey Mine, Rag Mine, and Knowles ironstones. His eyes, now sharpened by experience in collecting, soon discovered that these seams were the rich repositories of fish-remains, in a most excellent state of [redacted]

respects, unique collection of fossil-fishes. His everyday work as a mining man was bound to impress him with the importance of indicating the exact horizon from which these specimens were derived, although at that period, palæontologists were largely indifferent to information concerning horizons; and no one has done more than Mr. Ward, by precept and example, in teaching the necessity for care in this matter and its value in Coal-measure stratigraphy.

The young collector and his collection at length became known to R. Garner, the author of the *Natural History of the County of Stafford*, who helped him to begin the systematic study of the fossils which he so diligently acquired, and thus gave him the crucial twist that converted the mere collector into a scientific worker. About this time, also, he made the acquaintance of William Molyneux, another energetic investigator in Coal-measure geology. The influence of these two workers upon one another's development and outlook could not fail to be most marked. At the outset of their intimacy, there was friendly rivalry in securing the fish-remains from the ironstones already referred to, which were then being generally mined in the district where they resided. Afterwards, joint excursions farther afield to Churnet Valley, Cheadle, or Goldsitch Moss were undertaken by them, and through the communication of papers by Garner and Molyneux to the British Association for the Advancemént of Science, Mr. Ward's collection was brought to the notice of the most accomplished ichthyologists of the "sixties." He thus entered into correspondence—exchanging specimens and information—with these authorities, amongst whom (excluding the names of living persons) may be mentioned the following:— E. W. Binney, E. D. Cope, J. W. Davis, Sir William Dawson, Sir Philip Egerton, Lord Enniskillen, R. Etheridge, T. H. Huxley, L. G. de Koninck, C. Moore, Sir Roderick Murchison, J. S. Newberry, Sir Richard Owen, J. W. Salter, Sir Warington Smyth, W. C. Williamson, and John Young.

A direct consequence of this recognition of his place as an original observer was the accumulation of a valuable and comprehensive library of memoirs and papers relating to the geology and palæontology of the Coal-measures, mostly presented by the authors themselves. In seeking for fish-remains, he insensibly graduated into a collector of fossil-shells and plants, and his life-

work was henceforth resolved into the study of all the organic remains of the Coal-measures of North Staffordshire. Sinkings were watched, marl-pits and other open-works were visited, with the object of determining the distribution, horizontal and vertical, of the fossils, and, also, with the possibility in view of discovering something new, either to science or to the locality or horizon.

The period of which the writer speaks, which witnessed the progress of Mr. Ward towards proficiency as a collector, was characterized by extraordinary activity in the same line of research in most of our coal-fields—the period signalized by the labours of Wm. Adams, J. Aitken, Thos. Atthey, T. P. Barkas, Jas. Bennie, G. P. Bevan, E. W. Binney, Thos. Craggs, J. W. Davis, Jos. Duff, Albany Hancock, Henry Johnson, Jas. W. Kirkby, William Molyneux, John Sims, and George Wild. It will be observed that, with a single exception or two, these men never reaped the full reward of their labours; many of them belonged to the humblest walks of life, aiming not at wordly advancement, and, of course, never receiving it. Mr. Ward was of this band, who held to Gilbert White's belief that "local information from actual observation tends more to promote natural history and science than all that is done by the speculations and compilations of voluminous authors." In gleaning this information, his energy never wearied and his zeal never flagged; even when in sight of the end, old collecting-grounds were re-visited, in the hope that something more might yet be garnered. As a

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sons scientific. The more subtle traits of the born collector, too, were his, namely, the possession of certain qualities of youth, its unworldliness, and indifference to material interests. Supplementary to these, and almost paradoxically, his methods in the field were distinguished by scrupulosity and keenness; the horizons and localities were searched systematically; the "finds" specially marked as soon as discovered; the note-book entered up on the spot, in such a clear manner that the notes might be as useful to any other person as to their author, and little further was necessary than to transcribe them as they stood. In this way, his localities were absolutely reliable, and his horizons remarkably accurate, considering that in so many instances when collecting on colliery spoil-heaps, he had to rely upon others for this information. As might be anticipated, in spite of the repeated checks that he imposed upon himself, some few errors in his earlier work have been brought to light by more recent investigation.

The material obtained by him was carefully worked over at home with the aid of needles, knife, chisel, and lens, and the lists then made out. But a full register of the fossil-fauna and flora of any locality was not the sole object that he kept in view; his interest in the wider questions of biology led him to gather together large suites of the same species, in order to examine more thoroughly the processes of variation. These methods, developed gradually, stamp him as a pioneer in what, in these days, is understood as "scientific collecting."

Many of his specimens are now exhibited in our large museums; the Natural History Museum at South Kensington possesses a fine collection of fossil-fishes (including the type-specimens as per Table I.); other fossils given by Mr. Ward may be seen in the provincial museums at Edinburgh, Manchester, Newcastle-upon-Tyne, York, and Leicester.

In the long run, however, his claims to remembrance will rest almost entirely upon his published scientific work, and friendship need not betray the writer into the use of overdrawn impressions in remarking upon it. The vast amount of palæontological material which Mr. Ward accumulated was generously placed at the service of others, and a glance at Table I. will show the indebtedness of science to him in this connection. The fishes were studied and described by J. W. Davis, Egerton, Huxley,

John Young, Dr. R. H. Traquair, and Dr. A. Smith Woodward; the molluscs by R. Etheridge, J. W. Salter, and Dr. Wheelton Hind; the ostracods by Prof. T. Rupert Jones and J. W. Kirkby; and the plants by Mr. R. Kidston. Thus it will be seen how seldom he himself described those species, new to science, which

TABLE I.—List of Type-fossils.

Name of Fossil.	Author.	Where Described.
Fishes:		
Acanthodes Wardi	Sir P. Egerton ..	*Q. J. Geol. Soc.*, 1866, vol. xxii., page 468, plate xxiii.*
Acanthodopsis microdon	R. H. Traquair ..	*Ann. and Mag. Nat. Hist.* (6), vol. xix., plate 1, fig. 7.*
Cheirodus granulosus	John Young ...	*Q. J. Geol. Soc.*, 1866, vol. xxii., page 306, plate xx.*
Cycloptychius carbonarius	John Young; figured by R. H. Traquair	*Rep. Brit. Assoc.*, 1865, p. 319. *Geol. Mag.* (2), 1874, vol. i., page 241, plate xii.*
Diplodus equilateralis	John Ward ..	*Trans. N. Staffs. Inst. Min. Engrs.*, 1890, vol. x., page 139, plate 2, fig. 2.*
Elonichthys caudalis	R. H. Traquair ...	*Palæont. Soc.*, 1877, p. 53, plate v., figs. 1 to 4.*
Elonichthys microlepidotus	R. H. Traquair ...	*Geol. Mag.* (3), 1886, vol. iii., page 441.*
Elonichthys oblongus	R. H. Traquair ...	*Palæont. Soc.*, 1877, page 55, plate vi., figs. 1 and 2.*
Elonichthys semistriatus	R. H. Traquair ...	*Palæont. Soc.*, 1877, page 49, plate iii., figs. 9-12.*
Eurylepis anglica	R. H. Traquair ...	*Ann. and Mag. Nat. Hist.* (6), vol. xiv., page 249, plate ix.*
Gonatodus Molyneuxi	R. H. Traquair ...	*Geol. Mag.* (3), 1888, vol. v., page 252.*
Listracanthus Wardi	A. S. Woodward	*Geol. Mag.* (4), 1903, vol. x., page 486, figs. 1 to 8.*

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he discovered. He was an expert ichthyologist, and might have done this for the fishes, this omission being due, in a great measure, to his lack of self-confidence, for he was modest with an exceeding modesty; and but for this feature of his character he might have given, with his own hand, that finish to his scientific work which is so vital to perpetuation in the history of science.

A list of the type-fossils discovered by Mr. Ward is contained in Table I., which, in itself, forms a splendid record of one man's life-work; and, further, it is of special interest to the members of this Institute, inasmuch as all the specimens have been obtained from the North Staffordshire coal-field.

Of Mr. Ward's contributions to the literature of Coal-measure geology, the most considerable are those relating to the distribution of the organic remains of the coal-fields of North Staffordshire (Appendix, *Bibliography*, Papers Nos. 7, 14, 29, and 31), and they represent an immense devotion of time and labour to this investigation, not only in the field, but also in the study.

In the first of these (Appendix, *Bibliography*, Paper No. 7), he points out the difficulty in correlating seams of coal and ironstone in this district, owing to the rapid changes in their physical characters, and suggests to mining engineers the advisability of giving more attention to the fossils occurring in the measures through which they pass in sinking and crutting operations, and announces that "many of the seams have characteristic fossils" (page 185). In this statement lies the germ of what, in later years, has expanded into the zoning movement in Coal-measure stratigraphy. In the same paper he insists on the value, as index-beds, of the thin entomostracan limestone, 12 yards above the Bassey Mine, and of another near the base of what is now regarded as the Newcastle-under-Lyme Group. The former band he traced from Longton to Burslem, and for this reason it is now frequently denominated "Ward's Limestone."

The memoir (Appendix, *Bibliography*, Paper No. 14) appeared in our own *Transactions*, and forms, probably, the most valuable geological paper ever brought before a purely mining society in this country. In this monograph, Mr. Ward adopted the (at that time) orthodox subdivision of the Coal-measures of North Staffordshire into "Upper," "Middle," and "Lower"—a classifica-

tion clearly inadequate, because inapplicable for correlating the Potteries and the Cheadle coal-fields as treated in that paper. The memoir, however, was distinguished by its valuable fossil-lists from various horizons, and by its beautiful figures of fossil-fishes. These plates will always bear eloquent testimony to the judgment and enterprise shown by the Council of this Institute in its early days, and may serve as an object-lesson to more ambitious societies in this important detail of their publications. Another feature of this monograph was the prominence given to the occurrence of marine bands in the Coal-measures, which had been detected at two or three localities in the Longton district. Valuable observations are offered on the fossil-forms discovered therein, but no attempt was made to trace the horizons further. At that time, each horizon was identified by its position with respect to a known coal-seam. This may be taken as an admirable illustration of the unforeseen advantages to industry which arise out of researches undertaken in theoretical science: for, as a result of more recent work, marine beds in Coal-measures now serve to identify our coal-seams. This memoir discloses, on the part of the author, the possession of the faculty of analysing scientific data and of presenting such in a lucid and logical manner.

As a list of organic remains derived from one British coal-field, it is only surpassed by the same author, when, subsequently, he contributed the palæontological section to the *Memoir of the Geological Survey* dealing with the North Staffordshire coal-

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tion, abandoned the old classification of the Coal-measures, because, in his view, after long years of search and enquiry, no simple lines of demarcation could be drawn which would meet the requirements of the threefold division of the series.

A pathetic interest attaches to the last paper that he published (Appendix, *Bibliography*, Paper No. 31), for during its preparation he was suffering from what proved to be a fatal illness. In the geological literature relating to the Cheadle coal-field, there was a great gap which this paper, to some extent, fills, and no other person than Mr. Ward possessed the information concerning the palæontology of this district. For some inexplicable reason, the lists of fossils, when offered for publication in the *Memoir of the Geological Survey* dealing with this coal-field, were not accepted—to the detriment, certainly, of that memoir. Hence, the importance of this contribution, based on investigations which extended over a long period of years that offered facilities for collecting from some horizons such as may possibly never recur.

Mr. Ward's work, however, was by no means confined to scientific research; he lived "the strenuous life," and all movements for social and intellectual betterment had his active support. He was connected with the public life of Longton for 34 years, having been elected a councillor in 1872 and an alderman in 1874. He was particularly identified with the public-library movement in that town, having acted as honorary secretary of the Athenæum and Mechanics' Institute, and as chairman of the Free Library Committee from 1897 till the time of his death. His influence in the selection of periodicals, journals, papers, and books provided by that institution, made for catholicity and for the highest excellence. He found time to enjoy much of the current magazine-literature, and among recent publications of general literature he contrived to peruse those relating to biography and travel.

He was a member of the Stoke-upon-Trent Board of Guardians for twenty years, and in 1902 he was made a Justice of the Peace for the borough of Longton; his record of municipal service, therefore, indicates a life-long devotion to a high sense of public duty.

He was one of the original members of the North Staffordshire Naturalists' Field Club; to the very last he regularly attended its meetings, and his contributions from time to time added distinction to its reports.

He was a member of this Institute in its pre-federated days, when he frequently assisted with the editorial work in connection with the *Transactions*, and, as an acknowledgment of the importance of his investigations in local geology, he was elected an honorary member of this Institute in 1901.

In 1895, he received the Garner Medal for "his researches in the geology and palæontology of the North Staffordshire coal-fields," and, in 1899, the Geological Society of London gave him the Lyell Award in recognition of his "long services to the geology of his district."

His death occurred at Longton on November 30th, 1906: In years to come, wherever the science of Coal-measure geology is followed, his name will be kept familiar to students by being identified with the fossil-species enumerated in Table II.

TABLE II.—LIST OF FOSSIL-SPECIES DEDICATED TO MR. WARD.

Name of Fossil.	Author.	Reference.
Acanthodes Wardi ...	Sir P. Egerton ...	*Q. J. Geol. Soc.*, 1866, vol. xxii., page 468, plate xxiii.
Acanthodopsis Wardi	R. H. Traquair ...	*Ann. and Mag. Nat. Hist.* (6), vol. xix., plate i., fig. 7.
Hybodopsis Wardi...	W. J. Barkas ...	*Monthly Rev. Dental Sci.*, vol. vii., page 191, figs. 1 to 6.
Listracanthus Wardi	A. Smith Woodward	*Geol. Mag.* (4), 1903, vol. x., page 486, figs. 1 to 8.
Mesolepis Wardi ...	John Young ...	*Q. J. Geol. Soc.*, 1866, vol. xxii., page 313, plate xxi., figs. 1 and 3.
Rhadinichthys Wardi	J. W. Davis ...	*Q. J. Geol. Soc.*, 1880, vol. xxxvi., page 334, plate xii., fig. 6.

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too, "took fortune's buffets and rewards with equal thanks." After all, his work was his life, and his work remains; it is

"Enough if something from his hands have power
To live, and act, and serve the future hour."

APPENDIX.—BIBLIOGRAPHY OF PAPERS BY JOHN WARD.

1. "Fenton Park: its Ichthyolite remains," *Potteries Mechanics' Magazine*, 1861, vol. ii., page 137.

2. "Marine Fossils in Coal-measures, Longton," *Geological Magazine*, 1865, vol. ii., pages 284 and 286.

3. "The Distribution of the Organic Remains of the North Staffordshire Coal-field," *Transactions of the Dudley and Midland Geological Society*, 1865, vol. ii., page 21.

4. "Notes on the Fossil Trees in Messrs. Hampton's Marl-pit at Joiner's Square, Hanley," *North Staffordshire Naturalists' Field Club*, 1870, *Report*, page 28.

5. "The Fossil Fishes of the North Staffordshire Coal-field," *Transactions of the Midland Scientific Association*, 1870, part ii.

6. "Notes on Fossil Trees in a Marl-pit at Hanley," *North Staffordshire Naturalists' Field Club*, 1875, *Report*, vol. iii., page 27; *ibid.*, 1875, *Addresses and Papers*, page 80.

7. "On the Organic Remains of the Coal-measures of North Staffordshire, their Range and Distribution; with a Catalogue of the Fossils and their Mode of Occurrence," *North Staffordshire Naturalists' Field Club*, 1875, *Addresses and Papers*, page 184, with plate.

8. "Presidential Address," *North Staffordshire Naturalists' Field Club*, 1876, *Report*, page 24.

9. "Notes on some Fossil Trees in a Marl-pit at Joiner's Square, near Hanley," *North Staffordshire Naturalists' Field Club*, 1880, *Report*, page 84.

10. "The Deposition of the Flora of the Carboniferous Period in the Coal-measures," *North Staffordshire Naturalists' Field Club*, 1881, *Report*, page 13.

11. "Obituary of W. Molyneux," *North Staffordshire Naturalists' Field Club*, 1883, *Report*, page 101.

12. "Some of the Earliest Forms of Vertebrate Life," *North Staffordshire Naturalists' Field Club*, 1884, *Report*, page 55.

13. "The Lower Coal-measures of the Cheadle Coal-field, with special reference to the recent Boring for Ironstone at Park Hall Colliery, Cheadle," *North Staffordshire Naturalists' Field Club*, 1889, *Report*, page 88.

14. "The Geological Features of the North Staffordshire Coal-fields: their Organic Remains, their Range and Distribution; with a Catalogue of the Fossils of the Carboniferous System of North Staffordshire," *Transactions of the North Staffordshire Institute of Mining and Mechanical Engineers*, 1890, vol. x., pages 1 to 189, and plates i.-ix.

15. "The Longton Athenæum and Mechanics' Institution, its Rise and Progress," 1891.

16. "The Progress of Geological and Palæontological Research in North Staffordshire," *North Staffordshire Naturalists' Field Club*, 1893, *Report*, page 67.

17. "Summary of Literature relating to the Geology, Mineralogy, and Palæontology of North Staffordshire, chronologically arranged," *North Staffordshire Naturalists' Field Club*, 1893, *Report*, page 97.

18. "The Occurrence of Marine Fossils in the Coal-measures of North Staffordshire," *North Staffordshire Naturalists' Field Club*, 1895, *Report*, vol. xxix., page 129; and the *Colliery Guardian*, 1895, vol. lxx., page 1132.

19. "Summary of Literature relating to the Geology, Mineralogy, and Palæontology of North Staffordshire," *North Staffordshire Naturalists' Field Club*, 1895, *Report*, vol. xxix., page 105.

20. "Geological Research in North Staffordshire," *Colliery Guardian*, 1891, vol. lxxi., page 612.

21. "Ecclesiastical History of Fenton," *Fenton Church Bazaar Handbook*, January, 1897.

22. "Summary of Literature relating to the Geology, Mineralogy, and Palæontology of North Staffordshire," *North Staffordshire Naturalists' Field Club*, 1899, *Report*, vol. xxxiii., page 72.

23. "Contributions to the Geology and Palæontology of North Staffordshire, No. 1, 'On a newly-discovered Marine Bed in the Coal-measures,'" *North Staffordshire Naturalists' Field Club*, 1900, *Report*, vol. xxxiv., page 87, and the *Colliery Guardian*, 1899, vol. lxxviii., page 1036.

24. "Contributions to the Geology and Palæontology of North Staffordshire, No. 2, 'Notes on Labyrinthodonts from the North Staffordshire Coal-field,'" *North Staffordshire Naturalists' Field Club*, 1900, *Report*, vol. xxxiv., page 101.

25. "Contributions to the Geology and Palæontology of North Staffordshire, No. 3, 'On the Occurrence of Labyrinthodont Remains in the Keuper Sandstone of Stanton,'" *North Staffordshire Naturalists' Field Club*, 1900, *Report*, vol. xxxiv., page 108.

26. "Summary of Literature relating to the Geology, Mineralogy, and Palæontology of North Staffordshire," *North Staffordshire Naturalists' Field Club*, 1902, *Report*, vol. xxxvi., page 94.

27. "Contributions to the Geology and Palæontology of North Staffordshire, No. 4, 'On a Fragment of the Tusk of a Mammoth from Fenton; with Notes on previous Discoveries of Mammalian Remains in North Staffordshire,'" *North Staffordshire Naturalists' Field Club*, 1902, *Report*, vol. xxxvi., page 92.

28. "Contributions to the Geology and Palæontology of North Staffordshire, No. 5, 'Additional Notes on a Section at Weston Sprink,'" *North Staffordshire*

[redacted]

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MARCH 10TH, 1908.

MR. JOHN ASHWORTH, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBER—

Mr. J. E. H. LOMAS, Mechanical and Mining Engineer, 32, Great St. Helens, London, E.C.

MEMBER, NON-FEDERATED—

Mr. WILLIAM CLIFFORD, Mining Engineer, Jeannette, Pennsylvania, United States of America.

Mr. GEORGE H. WINSTANLEY read the following paper on "Accidents in Winding, with special reference to Ropes, Safety-cages, and Controlling Devices for Colliery Winding-engines":—

ACCIDENTS IN WINDING, WITH SPECIAL REFERENCE TO ROPES, SAFETY-CAGES, AND CONTROLLING DEVICES FOR COLLIERY WINDING-ENGINES.

By GEORGE H. WINSTANLEY, F.G.S., M.Inst.M.E., Lecturer in Mining, Manchester University.

The official statistics for the year 1907, relating to accidents in mines,* show that at the collieries of Great Britain during last year there were seventy-one shaft accidents, which resulted in the loss of ninety-seven lives—a figure considerably in excess of the average of the last twenty-five years, and one which has only been exceeded three times, and equalled twice, during that period. These records do not take into account those occurrences—serious enough in themselves—which fortunately were not attended by personal injury or loss of life.

That the subject of shaft accidents and safety in winding has attracted the attention and engaged the interest of the mining community at home and abroad, is evinced by the evidence submitted to the Royal Commission on Safety in Mines, now engaged upon its deliberations, as well as by the Report, published at Pretoria in 1907, of the Transvaal Commission, which was [redacted]

to the records of new patents, published in the technical press, from which it is abundantly evident that the habitual inventor invariably includes in his repertoire a "Safety-device for Mine-cages, Hoists, and the Like," a fearful and wonderful contrivance to accomplish all manner of marvellous things "when the rope breaks."

The writer has observed close upon a hundred of these appliances, but quite the most weird is one referred to in the following extract from a patent specification, published some little time back in one of the mining newspapers:—

9013 (1906).—"Safety-appliances for Miners Descending into or Leaving the Shaft.—This invention refers to a safety-appliance to be used with ascent and descent cages for mine-shafts, of the kind wherein the cage is attached to a rope which is coiled and uncoiled on a drum by the winding-engine. On a supplemental drum, which in certain circumstances may be connected with the main drum for the cage-rope, a separate safety-rope is provided, which the miner fastens around his body. This rope is uncoiled to exactly the same length as the cage-rope. If the latter should break, the miner who has the safety rope attached to his body will be suspended, and can be let down or drawn up as desired."

The Transvaal Commission investigated between eighty and ninety "safety-"appliances of one sort or another, of which seventy-two were of the "when-the-rope-breaks" type. Of these latter, out of seventy-two, only two were reported upon with anything like definite approval; and even these, on careful examination, are not likely to commend themselves to practical men, nor are the views of the Commission with regard thereto very convincing.

The fact of the matter is that the breaking of a colliery winding-rope, whenever it does occur, is more likely to be the result than the cause of an accident. The writer has been unable to discover a single instance in which the breaking of a winding-rope, in the ordinary course of working, was positively shown to be, primarily, the cause of an accident—except in those cases where it was only too clear that the rope had been neglected or wrongfully treated.

It will no doubt be readily agreed that a rope cannot and will not break without a cause, and that if it is made of the best material, properly proportioned to the load which it has to carry, and fairly treated, it will not break, unless it be subjected to a strain exceeding its tensile strength. It is only too obvious, for example, that a rope having a tensile strength of 100 tons, must

have at least that amount of strain put upon it before it will break, unless it has been seriously weakened by improper use. It is equally obvious, too, that if such a rope does actually break, either the normal conditions of working must have been very greatly exceeded, or the rope must have been neglected or subjected to improper treatment.

The most effective course to pursue in order to prevent ropes from breaking is that which will prevent the normal conditions of working from being seriously exceeded, at the same time giving to the rope that constant and careful attention which its importance demands. The adoption of a so-called "safety-cage" is not the remedy. Safety-cages do not prevent serious strains upon the rope, neither do they ensure against neglect; but on this point more will be said hereafter.

It appears probable that many occurrences described as accidents are, strictly speaking, not so. An accident is an occurrence of an entirely unforeseen character, usually the result of a combination of unexpected circumstances which it was beyond human power to anticipate and provide against. Any occurrence which might have been prevented, either by the exercise of reasonable foresight or precaution, or the possession of reasonable knowledge and skill, cannot, the writer ventures to suggest, truly be regarded as an accident.

It is, of course, quite possible that some of those seventy-one occurrences recorded as shaft accidents were of this description, [redacted]

The Factor of Safety in Colliery Winding-ropes.—In good British colliery practice it has become almost universal to allow a factor of safety of 10 for colliery winding-ropes. The Transvaal Commission considered this question, and appears to have come to the conclusion that a factor of safety of 6 was a sufficiently liberal allowance.* The Transvaal Commission may be right in its conclusion, at least so far as conditions in South Africa are concerned; but the writer would be sorry to think that a similar conclusion would be accepted in this country, or that the more liberal figure of 10 were to be reduced. Indeed, it would not be amiss, since legislation is likely to result from the Royal Commission's deliberations, if the factor of safety in colliery winding-ropes were to be defined by law, just as the strengths of boiler-plates and other materials are regulated by the Board of Trade. In speaking of the factor of safety of 10, it should be clearly understood that the intention is to provide, at the outset, a rope which shall have a strength of not less than ten times the gross load to be raised, this gross load being made up of the weight of the cage, the tubs with their full weight of coal, and the weight of the rope itself.

The steel wire used in the manufacture of the best qualities of winding-ropes has usually a breaking strength of from 100 to 120 tons per square inch of sectional area. The writer offers for what it is worth a simple rule, by which the weight in pounds per yard, and the size of a winding-rope suited for a given load and depth of shaft, can be calculated with fairly accurate results. It must, however, be understood to refer only to round wire ropes of the usual construction, made of high-grade wire having a tensile strength of about 120 tons per square inch. It is based upon the fact that in round numbers the weight of 20,000 yards of such a rope, of any size, is practically equal to its breaking strength, and that the weight of 2,000 yards therefore represents its safe working-load. The rule is as follows:—Take the maximum suspended load in pounds (that is, the total weight of the loaded cage) and divide by the difference between 2,000 and the depth of the shaft in yards. Thus, take a load of 8 tons, and a shaft 600 yards deep.

$$\frac{8 \times 2{,}240}{2{,}000-600} = \frac{17{,}920}{1{,}400} = \text{say, } 12\tfrac{3}{4} \text{ pounds per yard.}$$

* *Report of a Commission appointed by His Excellency the Lieutenant-Governor [of the Transvaal] to enquire into and report upon the Use of Winding-ropes, Safety-catches and Appliances in Mine-shafts*, 1907, with Minutes of Evidence, page xxx.

The nearest rope to this, in the list of a wellknown manufacturer, under the head of "improved plough-steel" is one weighing 25 pounds per fathom, of which the breaking strength is stated to be 119 tons; the working-load will therefore be 11·9 tons.

Six hundred yards, at 25 pounds per fathom, amounts to 3·35 tons, giving a gross load of 11·35 tons, showing that the rule in this case gives a correct result. The square root of the weight in pounds per fathom is equal to the circumference of the rope in inches.

Certificates of Test.—When a new rope is purchased, the maker should be required to furnish a certificate of test, which should include both the wire used and a sample-length of the finished rope. The tests should be of as comprehensive a character as possible, embracing tensile, torsional, bending, and fatigue tests; and all the details should be fully set forth on the certificate.

The demand for so-called cheap ropes—that is to say, ropes which can be bought at a low figure per ton, but in practice prove really to be costly on account of their comparatively short life—has led to the manufacture of ropes that can be purchased at a price which, if the purchaser would only reflect for a moment, is very little higher than the cost of best-quality steel bar, and therefore leaves nothing for the various processes intervening between the raw material and the finished rope.

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material the cheap rope is made of, and by what processes it has been converted into wire.

All the operations which tend to make good material into good wire are operations which add to the cost, and if the purchaser insists upon a low cost, that is, a so-called "cheap" rope, he cannot in reason expect that he is getting the advantage either of good material, or of the best processes of manufacture. For example, the best steel for the manufacture of high-grade wire is made from Swedish iron, and one has only to look at the current market prices to see how this variety compares with others in point of cost. The subsequent processes may or may not include forging under the steam-hammer. If the hammer is dispensed with, an element of cost is eliminated, whilst a degree of quality is sacrificed. Cogging, rolling into rods, annealing, and cleansing precede the all-important process of wire-drawing, that extraordinary yet apparently simple process by which a steel rod is forcibly drawn through a hole smaller than itself, resulting in a rod or wire of reduced sectional area, but of greatly increased strength.

It is at this stage that expense may again be avoided by sacrificing quality in the finished article. A rod of given section may be drawn down to a wire of the desired tensile strength either by several gradual steps, or in a smaller number of steps with a greater proportionate reduction of sectional area at each stage. The resulting wire may have the same tensile strength, it may give the same torsional and bending tests, and it will obviously be cheaper to produce; but its life, under ordinary working-conditions, will be shorter, and it will do less work before broken wires begin to appear in the rope into which it has been made, the consequence being that the rope has to be discarded.

One of the first principles, and one of the most important essentials in connection with the efficient, economical, and safe working of winding-ropes, is this question of quality. It is important that purchasers and users should recognize what would seem to be a sufficiently obvious and self-evident fact, namely, that ropes of high quality cannot be purchased at an absurdly low figure. And further that there will always be found, in connection with all trades, makers who will undertake to find something sufficiently inferior to exchange for the price offered, no

matter how low. Indeed, this unfortunate tendency to insist on extreme cheapness in first cost, which never yet resulted in real economy, has had, and is having, a most deplorable effect upon manufacturing trades generally, and certain branches of the engineering industry in particular. It is not suggested that purchasers should pay fancy or exorbitant prices for what they require, but a little consideration will generally serve to show whether the price at which goods are offered can possibly permit of the use of the best materials and the most approved processes of manufacture.

As already pointed out, a rope may be manufactured from wire which has cost much less to manufacture than another wire, and yet the two samples of wire will satisfy the same tests as to tensile strength, torsion, and bending, but not fatigue. Formerly the only test for fatigue was that imposed by the ordinary conditions of working, and it is too late to discover, when the rope is done, that its capacity for work was not what was desired. Messrs. J. A. Vaughan and W. Martin Epton, however, have invented an appliance—illustrated in the Report of the Transvaal Commission*—which enables the fatigue-test to be applied. Briefly, the object of this machine is to enable a wire to be put under a load, say one-fourth of its tensile strength, and worked continuously round pulleys, bending in opposite directions, until fracture takes place. The pulleys, it must be remarked, are not small relatively to the diameter of the wire, but [redacted]

regards the strains to which it is subjected in working, but also with a view to avoiding excessive or rapid wear, internal abrasion and corrosion, matters of paramount importance which are only too frequently neglected. Assuming the rope to be made of suitable material, it will stand a considerable amount of bending and unbending on the drum and over the pulley, provided that the diameter is not too small in comparison with that of the rope. Nothing tends to shorten the life of a rope so much as bending and unbending on drums and pulleys which are too small. As a rule, however, this fault is more usually met with in haulage-drums and pulleys than in winding arrangements. The drums of winding-engines and the headgear-pulleys are generally more than 100 times the diameter of the rope, which, according to many rope-experts, is the minimum size of pulleys for six-stranded seven-wire ropes.

At the same time, so far as the headgear-pulleys are concerned, one must avoid the opposite extreme, and, if the pulleys exceed 18 feet in diameter, they become unnecessarily heavy, and lead to trouble and excessive local wear, in consequence of their inertia and momentum.

There can be little doubt that side-friction, caused by the rope rubbing against the cheeks of the headgear-pulley and against the coils of rope already on the drum, is responsible for a good deal of wear tending to shorten the life of the rope. The acuteness of the angle contained between the rope hanging in the shaft and the line of rope from the drum to the pulley (that is, the angle in the vertical plane), does not in itself seriously affect the question—provided that the pulleys are of the proper size; but the lateral angle (that is, the angle contained between the line of the rope from pulley to drum, when the cage is at the surface, and the line of rope from pulley to drum when the cage is at the bottom of the shaft) has undoubtedly an important bearing on the subject. And inasmuch as an acute vertical angle is generally caused by the drum being too near (measured horizontally) the pulleys, the acute vertical angle is often erroneously regarded as the cause of the mischief, whereas it is really the lateral angle caused by the amount of lateral travel on the drum. This will, of course, be greater for deep shafts than for shallow ones, and greater on small drums than on large drums. To avoid excessive side-friction, therefore, the relative position of the drum and pulleys

must be carefully proportioned, and the size of the drum must bear some relation to the depth of the shaft.

The greatest care must be taken, too, that the rope does not rub, or even occasionally knock, against anything in working. One frequently sees, on the sides, top, and bottom of the opening in the engine-house wall, through which the ropes pass, clear and abundant proof that they do at times rub against these surfaces, and such rubbing is not calculated to do them any good or prolong their life. Indeed, in collecting information for this paper, the writer has been surprised at the many different ways—simple and trifling enough in themselves—in which good winding-ropes are injured, even at collieries where there is an evident desire to do things properly and well. Doubtless it is the fact that these details are simple, and apparently trivial, which leads to their existence and their effect being overlooked. Bolt-heads in the drum projecting above the surface of the lagging, in consequence of wear, have been the cause of broken ropes.

Corrosion and internal abrasion generally go together, and are due to the neglect of proper cleaning and lubrication of the rope. The writer makes use of the word "lubrication" as quite distinct from "greasing." In the ordinary course of working, the wires in a rope move slightly and rub against each other, and efficient lubrication is therefore just as necessary as it is in the case of the moving-parts of a machine. To be effective, the treatment, however, must be that of lubrication and not mere [redacted]

The Life of Colliery Winding-ropes.—In good practice a winding-rope is not retained after it has begun to show outward and visible signs that its working-life is approaching completion. It is not easy to find a means of satisfactorily expressing or comparing the life of a colliery winding-rope. To measure its life merely in terms of months or years is obviously unsatisfactory. One rope may do more work in a few months than another one in as many years. Neither is it altogether satisfactory to express the life or work of the rope in tons of coal raised, although this is, of course, the usual way of arriving at its cost for purposes of comparison with other ropes. For example, we may be told that two ropes have respectively raised one million tons, and half-a-million tons. At first sight the former would be considered as having done twice as much work as the latter. If, however, we are further told that the former raised its million tons from a depth of 600 feet, whilst the latter worked in a shaft 2,400 feet deep, it will be apparent that really the rope which has raised 500,000 tons through a distance of 2,400 feet has done twice as much work, in foot-pounds or foot-tons, as the one which has raised 1,000,000 tons through a distance of 600 feet.

But even a record of tons of coal, or other materials raised, and the depth of the shaft, does not furnish a complete statement of what the rope may have accomplished. The average speed of winding has an important bearing on the question, whilst the weight of coal raised does not take into account what may possibly amount to a far greater total weight lifted during the life of the rope, namely, the weight of the cage and tubs and the weight of the rope itself. It is quite certain that in the generality of cases the work done by a winding-rope is three times as much as that represented by the coal raised. Regarded in this way, the work which is safely and satisfactorily accomplished at a very large number of British collieries by high-class winding-ropes, runs into astonishing figures. A rope which raises 500,000 tons from a depth of 1,600 feet runs up a total of 800 millions of foot-tons in coal raised; and, taking into account what is done in raising its own weight and the weight of the cage and tubs, a total of certainly not less than 2,500 million foot-tons.

There is, therefore, no reason for lack of confidence in steel-wire winding-ropes. It is possible to procure ropes which can be

absolutely relied upon to do, without fear of breaking, what they are required to do, and breakage will only result either from serious neglect or from strains so greatly in excess of working-conditions that something must go, and if the rope does not, something else will.

Rope-cappings and Attachment to the Drum.—Ample strength in the rope itself is, of course, of no avail if its attachment to the drum on the one hand, or to the cage on the other, is not proportionately strong. The former attachment to the drum is comparatively easily provided for, by taking advantage of what is known as coil-friction. It is usual to purchase a rope of considerably greater length than is represented by the distance from the drum to the bottom of the shaft, so that when the cage is at the bottom there are still three or four complete coils left on the drum. These extra coils not only provide spare rope to make up for the pieces which should be cut off at each re-capping, but they also serve to secure the rope to the drum.

In the light of the experiments recently reported and commented upon by Mr. John Gerrard, H.M. Inspector of Mines, with regard to rope-cappings, demonstrating that the form of capping which was perhaps most popular, and generally considered to be the best, really possessed a strength of from only 50 to 60 per cent. of the strength of the rope,* there is something very like irony in the situation. There can be little doubt that until Mr. F. L. Ward, of Bradford colliery, Manchester,

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exerting a force of 20 pounds to resist a pull of something like 200 tons, that is, if the rope were capable of sustaining such a strain.

The co-efficient of friction between a greased wire-rope and a wood-lagged drum will probably be about 0·35, which means that one coil on the drum would enable a pull of 1 pound to resist a strain of 9 pounds, two coils 9×9, three coils $9 \times 9 \times 9$ and four coils $9 \times 9 \times 9 \times 9$, or 6,561 pounds. With four coils on the drum, therefore, and the end passing through the lagging secured with a force of, say, 50 pounds, the rope is securely held, even if the load amount to as much as 140 tons.

One frequently finds that the rope-end which is passed through the drum-lagging is given two or three turns round the drum-shaft, in which case the security is increased to an enormous extent, and there is not the slightest necessity for the two or three strong clams which generally complete the arrangement. Yet at the other end of the rope we have been satisfied with an attachment only giving half the strength of the rope.

The experiments already referred to demonstrate, however, that too much care cannot be exercised in the selection, design, and application of rope-cappings. The forged steel conical socket, in which the prepared end of the rope is secured by means of white metal, when properly and carefully made, possesses a greater strength than the rope to which it is fitted. It must, however, be properly made, and the writer cannot do better than refer the members to Mr. John Gerrard's Report for 1906 for instructions on the most important points.*

Another excellent type of capping, which the writer believes to possess the necessary qualification of gripping-strength greater than the strength of the rope, is the Becker capping, which has the important advantage that it can be taken to pieces at any time and the rope inspected right up to its actual extremity.

Re-capping Winding-ropes.—The importance of re-capping the winding-rope, at regular intervals, cannot be too strongly urged; and the reasons for so doing are not difficult to recognize. First, there is the fact that the wires immediately above the

* *Reports of John Gerrard, H.M. Inspector of Mines for the Manchester and Ireland District (No. 6), to His Majesty's Secretary of State for the Home Department, under the Coal-mines Regulation Acts, 1887 to 1896, the Metalliferous-mines Regulation Acts, 1872 and 1875, and the Quarries Act, 1894, for the Year 1906,* **pages 17 and 18.**

capping, at the point where the rope loses its flexibility as it enters the socket of the capping, are subjected to a certain amount of bending of a different character from that which other parts of the rope are called upon to bear. It would also appear that the strains set up in the rope towards the capping, in ordinary working, are of a more trying character than those in other parts of the rope.

In recapping the rope, which should be done three or four times a year, a suitable length of rope should be cut off with the old capping, a length not less than one-half of the circumference of the headgear-pulleys. There are certain points in the cycle of operations in winding which result in greater wear in the corresponding places on the rope than in other parts. For example, that portion of the rope which is in contact with the headgear-pulley when the cage is at the top and the bottom of the shaft respectively. The starting of the wind, and the manipulation of the engine to facilitate the loading and unloading of the various decks, induces greater frictional wear at these points. Another point where wear takes place, especially in quick-winding, corresponds with the point where the speed of the engine is checked, the point where the brake is applied to the drum, and the rope in turn acts as a brake to check the revolution of the headgear-pulley.

For these and other reasons it will be seen that only by cutting off a proper length of rope at each re-capping can the exces-

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set up in the rope in the regular course of working. Some of these strains are unavoidable, as, for instance, the extra strain in starting when the inertia of the loaded cage at the bottom of the shaft has to be overcome, as well as the extra strain during the whole period of acceleration. This may amount, and probably does in some cases, to very nearly double the weight of the suspended load. The strain at starting depends very largely upon the care and skill of the engineman; a sudden "snatching" sort of start imposes very great strains, the extent of which it is scarcely possible to calculate, but which may dangerously approach the limit of strength of the rope.

(*a*) *Acceleration.*—The strain due to acceleration, that is, uniform acceleration, is as nearly as possible 70 pounds per ton for each foot per second in the rate of acceleration. Thus, supposing the gross load to be 10 tons and the rate of acceleration attained at one moment or another to be 25 feet per second, the extra strain would be $10 \times 70 \times 25 = 17{,}500$ pounds or nearly 8 tons, making for that particular moment the total strain 18 tons instead of 10.

(*b*) *Retardation.*—Another unavoidable extra strain is that which is occasioned when retarding the movement of the engine by the application of the brake. In this case the descending rope is subjected to a strain greater than that due to the actual suspended load; but here, again, if the engine is properly controlled and the brake is properly applied, the extra strain is amply covered by the factor of safety. There are, however, cases on record where the sudden application of a powerful brake has most probably been the cause of a serious accident. When one enquires into this matter closely, the result is at first sight somewhat startling and unexpected, although a little consideration will serve to show that it is the only result that really could be expected. Briefly it is this, that in the case of the sudden application of a powerful brake, whilst the engine is travelling at a fairly high speed, it is the rope attached to the ascending cage, and not that which is descending, which runs the greater risk of being broken.

A simple example will suffice to make this clear. Suppose we have a shaft where the ascending cage weighs 10 tons and the descending cage weighs 6 tons, and that the maximum speed is

80 feet per second. The ascending cage, at this velocity (neglecting friction), would continue to ascend for exactly 100 feet if the raising force were suddenly discontinued; that is to say, if such a thing were possible as the application of a brake which would stop the drum dead, the ascending cage would continue to ascend for a further distance of 100 feet before it came to rest, after which it would, of course, fall back.

The writer finds it necessary to say, at this point, that he does not suggest that it would actually be possible to stop the drum dead, or even in one revolution of the drum. A letter in one of the mining periodicals, criticizing a former paper on a somewhat similar subject, made it evident that the present writer's meaning had not been understood. His desire is to show that to stop a drum running at a high speed in a very short distance is not only impossible, but that to attempt to do it means destruction.

Coming back, then, to the example, let us suppose that the drum is brought to rest in a distance of, say, 90 feet, that is, 90 feet travel of the descending cage. The extra strain on the descending rope would—if the retarding force were uniform during the whole period—amount to rather more than double the actual weight of the suspended load, and this would doubtless be amply covered by the factor of safety.

The effect on the ascending rope, however, would be quite different: the strain would take the form of a sudden jerk, of

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Speed when brake applied.	Equivalent distance. $s=\frac{v^2}{2g}$	Speed when brake applied.	Equivalent distance. $s=\frac{v^2}{2g}$
Feet per second.	Feet.	Feet per second.	Feet.
10	1·56	60	56·20
20	6·25	70	76·60
30	14·07	80	100·00
40	25·00	90	126·60
50	39·00	100	156·09

In actual practice, it is not possible to exert a retarding force so perfectly uniform that we can reduce the speed of the drum and the cages at a perfectly uniform rate of 32 feet per second, which would be necessary in order to bring the cages safely to rest in the distances named above. It is therefore necessary to spread the retarding force of the brake over a much longer distance, and devote a larger portion of the space of time occupied in each run, to the slowing down and stopping, than is represented in the above figures.

The Use of Cage-supports or Keps.—A good deal of difference of opinion exists as to the use of cage-keps. Personally, the writer does not like them, if for no other reason than that they tend to shorten the life of the rope, and occasion great and jerky strains. With the cage resting on the keps, and 6 or 12 inches of slack rope or chain, it will be seen that quite a sudden and serious jerk can be given to the rope in snatching the cage from the supports. The writer has noticed that, where keps are regularly used, there is always a great deal more banging and bumping about of the cages than where they are not used.

Tests carried out under working conditions have shown that with less than 1 foot of slack chain the strain on the rope in picking up may be not far short of three times the actual load. A more doubtful arrangement is the mechanical kep, of which there are several types in use, by means of which the banksman can remove the keps from under the cage without troubling the engineman to raise it. By this appliance the banksman can let the cage actually drop on to the slack rope. The use of these appliances should, the writer considers, be prohibited, unless special arrangements are made for accurately adjusting the length of the rope, and extreme caution observed in avoiding slack rope when the keps are released.

Jerky Winding.—Jerky winding, with consequent sudden variation of strain on the rope, is either due to unskilful manip-

ulation, to a wrongly-proportioned engine, or to unsuitable controlling-appliances on the engine. That there are different degrees of skill amongst enginemen will be readily admitted. We have all experienced the difference in riding a cage when one or other of two enginemen has control. One man will produce a smooth and almost imperceptible gliding motion, whilst another, in charge of the same engines, will jerk the cage about until one has to grip the hand-rail with both hands to avoid being pitched out. But even a skilful engineman cannot avoid jerky action, if the engine is wrongly proportioned. If it is not so proportioned that either cylinder can start the load, with a reasonable rate of acceleration, there is a temptation to start with a run or jerk, so as to get over the dead centre.

The control of the engine should be such as to entail the least possible amount of physical exertion on the part of the engineman. His duties are such that, if he is to carry them out effectually, he must be free from constant demand upon his physical energy to operate and control the engine, so that his mental faculties may be properly concentrated upon his work. To this end the engine should have an easily-operated steam valve, quick to open and close; a steam-actuated reversing-gear, of which there are several excellent types in use; and a powerful brake, which, whilst capable of holding the engines under the most unfavourable circumstances, also permits of its being applied gradually so as to avoid the effects previously discussed.

If these appliances are unwieldy and heavy, and if the engine-

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every time. These operations he may have to repeat three or four hundred times a day, and the man who can do this, day after day, week after week, year in year out for many years, without ever making a mistake or committing an error of judgment, is, indeed, possessed of skill and ability of more than average character. As a matter of fact, it is too much to expect that an engineman will never make a mistake; and it should therefore be made incumbent upon colliery-owners to provide their engines with such controlling appliances as will relieve the engineman of undue physical exertion, and also to apply an automatic controlling-device which will positively prevent overwinding, running away, or starting in the wrong direction.

Controlling Devices for Winding-engines.—At a number of Lancashire collieries, for some years now, an appliance has been in use which goes a long way in this direction. The "Visor" is too well known to call for a description of its working; suffice it to say that the Visor makes running-away well nigh impossible, and absolutely prevents a quick overwind. In other words, it ensures that the speed of the engines, when approaching the end of the wind, shall be so far reduced that the question of final stopping is one of no difficulty.

A later appliance, and one which presents several interesting features, is the Whitmore controller, which is used in conjunction with the Whitmore steam-brake. In the Whitmore controller there are two long vertical screws, one having a right-hand and the other a left-hand thread. There is also a fly-ball governor which, as well as the two screws, receives motion from the engine. On each screw there are two nuts with projecting wings, and these nuts or cursors, separated by a few inches, travel up or down the screw as the engine works. The position of the nuts or cursors may, as a matter of fact, be regarded as indicating the position of the cages in the wind. The upper cursor in each case is to prevent overwinding even slowly, or starting in the wrong direction, and the lower cursor is to prevent the engine exceeding a certain predetermined speed at any point in the wind after the maximum speed has been attained. It not only limits the maximum speed, but it checks the proper and gradual reduction of speed as the engine approaches the end of its run.

The brake is of ingenious and yet simple construction, and is actuated by steam; the steam, however, is not the force which applies the brake, this being done by weights. The steam assists in putting on the brake, but it has to raise the weights in taking the brake off. The great advantage of this brake appears to be that the retarding force may be regulated to any degree between full on and full off, that the amount of retarding force is always the same for a corresponding position of the brake-handle, and that it may be very gradually increased until the full braking effect is produced, or, if need be, it can be applied quickly.

In conjunction with the Whitmore controller, its especial advantage is, that in the event of the controller coming into action to check the engine when running away, the brake is not applied too suddenly so as to produce the result that has been already indicated, but gradually, until the full retarding force is developed and the cages are brought to rest within a safe distance. An appliance of this kind is calculated to prevent an accident, not to come into operation afterwards with doubtful results. It does not and cannot interfere with regular and ordinary working, nor come into action when it should not.

Disengaging-hooks.—The use of disengaging-hooks has become very general, but it will doubtless be admitted that their sphere of usefulness is very limited. A detaching hook of the most perfect type affords no protection to the descending cage, whilst the protection that it affords to the ascending cage is limited to [redacted]

tion in which to approach the subject of safety in winding. It has too much the appearance of condoning carelessness or neglect in other directions, and it is perfectly certain that in nearly all cases where safety-cages could possibly be of service (even if there were any which were reliable), the accident would be due to neglect or carelessness. At the same time, the writer would not express this view so strongly, if it could be shown that such an appliance existed which could really stop the cage gradually and carefully. So far, there are none which can be relied upon to do so.

Briefly, safety-cages may be classed under two heads:—First, those in which the inventors have entirely lost sight of the fact that kinetic energy has to be reckoned with, and that it is just as serious to attempt to stop a cage suddenly as it is to break the rope to which that cage is attached; secondly, there are those, very few in number, in which the inventor appears to have recognized that an attempt must be made to bring the cage to rest gradually. Those coming under the first head are not worth further thought; they are positively dangerous, and many of them would more frequently cause worse accidents than those which they are supposed to prevent. Those coming under the second head are too complicated or too unreliable for practical use. One of these consists of an arrangement for securely gripping the conductors if the rope breaks, but this does not immediately stop the cage. The cage is attached to the gripping device through the medium of a wire-rope coiled on a drum secured to the top of the cage. This drum is provided with a sort of automatic brake, which is applied with gradually increasing force as the safety-rope is paid out. The writer is inclined to the opinion that people who will not take the trouble to look after their winding-ropes will not give much attention to a complicated device of that kind, and if it did not cause an accident itself, in all probability it would be out of order when required to operate.

One of the safety-cages favourably reported upon by the Transvaal Commission* is a device consisting of a steel cylinder containing liquefied carbonic-acid gas, which, in the event of the rope breaking, operates two rams or pistons working in other

* *Report of a Commission appointed by His Excellency the Lieutenant-Governor [of the Transvaal] to enquire into and Report upon the Use of Winding-Ropes, Safety-catches and Appliances in Mine-shafts*, annexure No. 7, page ciii.

cylinders. These rams are designed to actuate brake-blocks which bear upon the rigid guides in the shaft, and bring the cage to rest more or less gradually. Again, the complication is too great, and again the writer finds himself asking the question whether it is likely that people who are going to neglect their ropes or treat them so that they will break, are the sort of people to keep in good working order a complicated apparatus of that kind. But in this particular case we have an object-lesson at first hand, the full particulars of which will be found in the report of the above-mentioned Commission.

On September 7th, 1906, seven members of the Commission, two officials, and one representative of the inventor conducted a practical test with this apparatus at the "Marcus" shaft, a shaft which had been placed at the disposal of the Commission for the purpose of such experiments. The first test, allowing the cage to fall from rest, was apparently successful. Then followed a more severe test, in which the cage was detached whilst descending. The cage dropped to the bottom of the shaft, there was no evidence of any retarding action, and it was found that there was no gas in the cylinder.* If this can happen in a specially conducted test, what could happen, one ventures to ask, in ordinary work, when there are no experts standing around to look after it?

But the last word about safety-cages has surely been uttered by the inventor of this appliance himself. The writer does not

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The writer commends the above expression of opinion, without comment, to his fellow-members for their most serious contemplation and meditation.

In conclusion, the writer feels that he may appear to have expressed some of his views very strongly, but in a matter of such great importance there is nothing to be gained by beating about the bush. He has no interest in any mining appliances, either connected with winding or other operations, except in so far as they lead to economy, efficiency, and safety; and wherever efficiency and safety are found there also will economy be found. Economy is not measured by the amount of expenditure incurred, but by the degree of efficiency and the standard of safety which can be maintained.

The PRESIDENT (Mr. John Ashworth, Manchester) thought that Mr. Winstanley's paper was of a most instructive character; the members present had been fully interested in it from first to last, and it had been illustrated by excellent slides. The paper showed how important it was, not only to have good laws, but to exercise the utmost possible care and one's best judgment in all circumstances.

Mr. HENRY HALL (H.M. Inspector of Mines, Rainhill, near Liverpool), in moving a vote of thanks to Mr. Winstanley, said that the pleasure of listening to this most excellent paper was enhanced by the fact that it came at a very opportune moment, as several very bad accidents had happened quite recently, due to causes mentioned by Mr. Winstanley. The first part of the paper might, however, lead to some misconception. The author had said a great deal about the qualities of wire used, and what bad ropes there were in the market, and left it to be implied that colliery managers might be willing to purchase some of those ropes of bad quality. In his judgment, colliery managers were not likely to do anything of the kind. If there was one matter as to which they should be careful, it was this question of the quality of the winding-ropes, because a bad rope might lead to serious damage to the mine in addition to the danger to life.

Mr. T. H. WORDSWORTH (Audenshaw, Manchester), in seconding the vote of thanks, said that the paper must have occupied

a good deal of time in its preparation, and that Mr. Winstanley had laid before them much valuable information.

The resolution was unanimously passed.

Mr. W. Ollerenshaw (Denton) said that Mr. Winstanley had previously read many excellent papers before the Society, but he thought that on this occasion he had excelled himself. He admired his courage in referring to defective ropes. Mr. Hall thought that colliery managers did not buy bad ropes; but the fact remained that manufacturers were selling them, and, therefore, somebody must be buying them. He believed with Mr. Winstanley that cheap ropes were not economical but expensive; yet no matter how good a rope was when first put to work, unless it received proper attention, was regularly cleaned and properly lubricated, rapid deterioration would soon result.

Mr. Leonard R. Fletcher (Atherton) thought that the factor of safety for winding-ropes need not be 10 in all cases. It seemed to him that there was a sufficient margin of safety for heavy loads with a factor of about 7. Assuming the loaded cage to weigh 10 or 12 tons, if the rope were made on the principle of being ten times stronger than the weight that it had to bear, a rope of large diameter would be required. If the cage were only 3 tons or thereabouts in weight, taking a factor of 10 they would get a rope that would not break under a less strain than 30 tons, thus allowing a margin of 27 tons. But, assum-

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factory results. He thought that Mr. Winstanley was labouring under a misapprehension in stating that a strong reason against using these patent keps was that the slack chain which might be resting on the top of the cage would go down with a jerk when these catches were drawn away. As a matter of fact, no slack chain would remain on the cage at the pit-top, as it would immediately be taken up by the weight of the other cage-rope hanging in the shaft. He had been very much interested in the paper, but thought that it would be a pity if anyone were prevented from using these patent keps by what had been stated by Mr. Winstanley; and it was only fair both to the makers and to those who used them, to state what had happened in actual practice. Personally, he would be sorry if, as Mr. Winstanley had suggested, any law were passed to compel a 10 to 1 factor of safety for winding-ropes, or to prohibit the use of these patent keps. The laws which they had at present to observe were as many as they could well remember, without adding to them unnecessarily.

Mr. S. Eckmann (Manchester) said that no reference was made in the paper to the safety-devices for electric winders. Mr. Winstanley had rightly emphasized the necessity for providing winding-engines with such controlling-appliances as would relieve the driver of undue physical exertion and would automatically prevent overwinding, running away, or starting in the wrong direction. The control-devices of electric winders, especially those after the Ilgner, Ward Leonard, or similar systems, were far superior to any of the appliances mentioned in the paper. They were well known, and had been dealt with in a previous paper.* The superiority of electric control had been recognized by Continental authorities by allowing the maximum speed of 33 feet per second for winding men with electric winders, as against a maximum of 18 feet with steam winders; indeed, when testing a new electric winding-engine, gentlemen had allowed themselves to be wound at a maximum speed of 60 feet per second. In another test, the driver of an electric winder was advised to start the engine and then go away, and to leave the retarding and stopping entirely to the automatic devices, with the result that the cage was stopped automatically at bank-level. The smooth running and, consequently, the reduced wear

* "The Application of Electricity for Winding and other Colliery Purposes," by Mr. Maurice Georgi, *Trans. M. G. M. S.*, 1904, vol. xxviii., page 455.

of the ropes and the greatly increased safety against accidents connected with electric winding-engines, were points well worth taking into account when the question of steam or electrically-driven winding-engines was under consideration.

Mr. A. Rushton (Abram, near Wigan) said that at the Abram pits they used cage-keps whilst the men were ascending and descending, after which they were pegged back for the rest of the day, and thereby wear-and-tear of the cages was saved, the cages always being suspended, and the ropes kept tight during the winding of coal. In these pits where the catches or keps were used and heavy weights were raised, a severe strain would be put upon the ropes by using the catches continually when the engine raised the load from the bottom, as the cages rested upon the catches and the rope was slack. At one of their pits, the weight raised from the bottom was 13 tons. He was in favour of using the catches for men, but did not deem them needful when drawing coal.

Mr. John Livesey (Bolton) urged the desirability of demanding a certificate with every rope purchased. Ropes could be obtained at any price, but Mr. Winstanley had not told them which was the best way to secure a good one. At present, they could only tell whether a rope was a good or a bad one after it had been in use.

Mr. John Gerrard (H.M. Inspector of Mines, Worsley) said

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supported the resort to mechanical arrangements to prevent undue speed, or the starting of the engines the wrong way, and to arrest the engines in case the engineman failed to do so. Detaching-hooks had made winding in shafts much safer, but they did not secure safety at other than moderate speeds, for every detaching-hook hitherto brought out had failed at full speed.

Mr. George H. Winstanley (Manchester), in acknowledging the vote of thanks, said that, with the President's permission, he would defer his reply to the various points raised until the adjourned discussion; but he would like to say, in answer to Mr. Fletcher, that he was willing to admit that the reference to mechanical keps might perhaps with advantage have been differently worded. As a matter of fact, in revising the proof he had made an addition which he feared did not appear in the advance-copies printed for use at the meeting.

What he had desired to convey, with regard to mechanical keps was, that perfect as such appliances might be mechanically, they were liable to very serious abuse, and if not applied and handled with the greatest possible care, their undoubted advantages might be converted into disadvantages.

He advocated in all mechanical appliances, so far as was reasonably practicable, arrangements which would refuse to act altogether unless properly operated. Mechanical keps—keps which obviated the necessity for raising the cage to effect their withdrawal—might be, and no doubt were, excellent appliances in themselves. But whilst on the one hand, when carefully used with regular adjustment of the ropes, they might be very convenient and give most satisfactory results, on the other hand, their actual operation was independent of the adjustment of the rope and the manipulation of the engine, and they could, as a matter of fact, be withdrawn when the rope was slack. For this reason, he had desired to introduce a reference that would call forth discussion, to emphasize the importance of extreme care in the application and use of these otherwise valuable appliances.

With regard to the factor of safety in winding-ropes, he was glad that that point had been taken up, and hoped that more would be said upon the subject at the adjourned discussion.

The further discussion of the paper was adjourned.

THE MINING INSTITUTE OF SCOTLAND.

ANNUAL GENERAL MEETING,
HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 9TH, 1908.

DR. ROBERT THOMAS MOORE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The Annual Report of the Council was read as follows:—

ANNUAL REPORT OF THE COUNCIL, 1907-1908.

On this, the thirty-first annual meeting of the Institute, the Council have the pleasure of submitting the thirtieth annual report.

The number of members on the roll, at this date, is as follows:—

Honorary members	4
Life members	8
Life associate member	1
Members (subscription £2 2s.)	172
Members (subscription £1 5s.)	297

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This shows a net increase in membership of 19 during the year.

Of the members deceased, particular reference may be made to Mr. M. Walton Brown, who was the Secretary of The Institution of Mining Engineers, and Mr. Robert L. Galloway, mining engineer, whose "History of Coal Mining in Great Britain" and "Annals of Coal Mining and the Coal Trade" give evidence of careful and accurate work as a mining historian.

The following papers, with discussions thereon, have been before the members and published in the *Transactions*:—

"Rescue-apparatus for Use in Mines." By Mr. James Bain.
"A Stretcher for Use in Mines." By Mr. John F. K. Brown.
"A Wagon-lowering Device for Use at Colliery Screens." By Mr. Thomas Train Christie.
"The Hanley Cage Guardian." By Mr. Albert Hanley.
"An Underground Diamond Bore at Prestonlinks Colliery." By Mr. Richard Kirkby.
"Notes on Some Tests and Results with an Oddie-Barclay High-speed Pump." By Prof. Charles Latham.
"Polmaise Collieries." By Mr. James Salmond.

Demonstrations were given of the Weg rescue-apparatus by Mr. W. D. Lloyd, manager of Altofts colliery, and of the Fleuss apparatus by Mr. A. H. Fleuss, the inventor.

With a view to the encouragement of mining students, an addition was made to the Rules during the year, to enable students' societies and classes to affiliate with the Institute on easy conditions; and already an application has been made by a students' association for affiliation.

The summer excursion was to the Polmaise collieries of Messrs. Archibald Russell, Limited, where a most enjoyable day was spent by a large contingent of the members.

The death of Mr. M. Walton Brown, which took place on November 22nd, 1907, necessitates the appointment of his successor as Secretary to The Institution of Mining Engineers, and this raises other questions such as headquarters and administration. These matters are receiving the careful attention of the Council of this Institute and of your representatives on the Council of The Institution of Mining Engineers. A committtee,

of which your President and Secretary are members, has been appointed to consider the whole question; and the recommendations of the Committee will be submitted to the Institute should any radical change be proposed.

The donations to the Library during the year, in addition to those received by exchange, are as follows:—

Donors.	Donations.
Dr. Robt. Thos. Moore.	Two guineas.
Mr. J. M. Ronaldson.	Mines Inspectors' Reports and Statistics, 3 volumes.
Mr. Robert McLaren.	Mines Inspectors' Reports, 1 volume.
Mr. A. R. Sawyer.	Paper on "New Rand Gold-field, Orange River Colony."

The exchanges now number 67, and are a most valuable source of supply for the library, embracing as they do the newest and best information in all departments of mining and engineering.

The Treasurer's accounts show that the Institute is in a satisfactory financial position.

There have been eight meetings of Council during the year.

The report was unanimously adopted.

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THE TREASURER IN ACCOUNT WITH THE MINING INSTITUTE OF SCOTLAND,
FOR THE SESSION 1907-1908.

RECEIPTS.			£	s.	d.
To Balance from Session 1906-1907			549	6	2½
„ Members' Subscriptions—					
„ Arrears—					
2 Members,	Session 1906-1907	at 42s. 0d.	4	4	0
2 Members,	„ „	„ 25s. 0d.	2	10	0
„ Subscriptions—					
166 Members,	Session 1907-1908	„ 42s. 0d.	348	12	0
287 Members,	„ „	at 25s. 0d.	358	15	0
12 Members,	„ „	„ 21s. 0d.	12	12	0
1 Member,	„ „	„ 10s. 6d.	0	10	6
31 Associate members,	„ „	„ 42s. 0d.	65	2	0
13 Associates,	„ „	„ 25s. 0d.	16	5	0
17 Students.	„ „	„ 25s. 0d.	21	5	0
2 Members,	Session, 1908-1909	„ 42s. 0d.	4	4	0
4 Members,	„ „	„ 25s. 0d.	5	0	0
„ Rents of hall			7	10	6
„ *Transactions*, etc., sold			1	2	3
„ Interest			20	4	5
„ Donation			2	2	0
			£1,419	4	10½

PAYMENTS.	£	s.	d.	£	s.	d.
By The Institution of Mining Engineers ...				531	2	5
„ Printing and stationery				53	10	10
„ Books and book-binding				17	17	3
„ Rents of halls, etc.				51	7	6
„ Electric lighting, gas, and assessments ...				12	6	11½
„ Stamps, telegrams, carriages, etc. ...				9	13	8½
„ Sundry payments				6	1	4
„ Salaries				101	8	0
„ Cleaning of halls				7	16	0
„ Expenses of Council				65	7	6
„ Cash in Post-office Savings Bank ...	85	3	3			
„ „ Investment, £200 2½ % Consols	170	15	0			
„ „ Commercial Bank—						
Current account	9	12	10			
Current deposit receipt ...	295	12	8			
„ „ Treasurer's hands	1	9	7½			
				562	13	4½
				£1,419	4	10½

Hamilton, March 31st, 1908.—Examined, compared with vouchers, and found correct.

R. W. DRON, } AUDITORS.
WM. McCREATH, }

ELECTION OF OFFICERS, 1908-1909.

Office-bearers for the session 1908-1909 were elected as follows:—

PRESIDENT:

Dr. Robert Thomas Moore, 142, St. Vincent Street, Glasgow.

VICE-PRESIDENTS:

Mr. James Hamilton, 208, St. Vincent Street, Glasgow.
Mr. Robert McLaren, 77, Colinton Road, Edinburgh.
Mr. Thomas H. Mottram, 6, Kelvinside Gardens, Glasgow.
Mr. Thomas Thomson, Fairview, Hamilton.

COUNCILLORS:

Mr. Thomas Arnot, Quarter Colliery, Hamilton.
Mr. Thomas Arnott, 12, Garrioch Drive, Kelvinside, Maryhill, Glasgow.
Mr. Harry D. D. Barman, 21, University Gardens, Glasgow.
Mr. Adam Brown, Allanton Colliery, Hamilton.
Mr. William Howat, North Motherwell Colliery, Motherwell.
Mr. Douglas Jackson, Coltness Iron Works, Newmains.
Mr. Thomas J. Jamieson, 7, Victoria Terrace, Levenhall, Musselburgh.
Mr. Richard Kirkby, Forth Collieries, Prestonpans.
Mr. James McPhail, Bog Colliery, Larkhall.
Mr. John Menzies, Auchinraith Colliery, Blantyre.
Mr. James B. Sneddon, Oakbank Mines, Mid-Calder.
Mr. John B. Thomson, Lilac Shieling, Lilybank Street, Hamilton.

ADDITION TO THE RULES.

The following additions to the Rules were adopted:—

3.—Council.—The Council of the Institute for the management of its affairs shall be chosen annually from the members, and shall consist of a President,

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12.—Candidates for the Council of the Institute shall be put in nomination at the general meeting preceding the annual general meeting, and Representatives on the Council of the Institution at the general meeting held in June in each year. The Council, by means of a printed circular sent to each member prior to said general meetings respectively, shall present a list of their retiring-members and Representatives, respectively, who offer themselves for re-election, together with the names of such other members as they may deem suitable for the various offices. Any member shall be entitled to add to the list of candidates, either personally at the respective meetings or by letter sent to the Secretary prior thereto, each such nomination, whether made personally or by letter, to be seconded by a member. When the nominations received exceed the number required, the election will be made by ballot at the succeeding meetings, respectively, prior to which a list of the candidates will have been issued to the members with the names of proposers and seconders. In case of the decease or resignation of any officer or officers, or Representative, notice thereof must be given at the next general or special meeting, and a new officer or officers, or Representative, elected at the succeeding general or special meeting, in accordance with the mode above mentioned.

DISCUSSION OF MR. RICHARD KIRKBY'S PAPER ON "AN UNDERGROUND DIAMOND BORE AT PRESTONLINKS COLLIERY."*

Mr. Robert Martin (Newmains) wrote that Mr. Kirkby's paper was most interesting, and indicated a further introduction of machinery into mines. The expression that the Great seam was "the topmost coal in the Edge Coal Series,"† was rather misleading. In the Mid-Lothian portion of the Musselburgh and Dalkeith coal-fields, the Edge seams occurred along the western outcrops, extending from the Forth at Portobello to the Carlops. In the centre of the basin, under Musselburgh town, the Great seam was the fifteenth or sixteenth workable seam from the top, and its position was about the middle of the Carboniferous Limestone Series. Eastwards behind Carberry and Roman Camp hills into East Lothian, all the upper and part of the lower seams were denuded, making the Great seam the topmost seam in that county. The western basin was deep and steep, and the eastern one shallow and flat. An "Edge coal," according to Mr. James Barrowman's *Glossary of Scotch Mining Terms*, was a seam "lying at a higher inclination than 1 in 1,"‡ or over 45 degrees, whereas Mr. Kirkby stated that the Great Seam dipped "due northwards at about 1 in 8" at Prestonlinks colliery.§

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 89. † *Ibid.*

‡ Page 26. § *Trans. Inst. M. E.*, 1908, vol. xxxv., page 89.

The progress in boring showed a rate of 5·3 feet per day. This might be an improvement on chisel-boring, but it was very slow as compared with other diamond-boring. He (Mr. Martin) knew of two diamond bores from the surface done by a wellknown firm. In one case, about 809 feet were bored at the rate of 18 feet per day; and, in the second case, 600 feet at the rate of 24¾ feet per day. This probably pointed to the desirability and profit of giving a greater head-room than was given in the case under discussion, namely, 15 feet. He (Mr. Martin) agreed with Mr. Kirkby regarding the cores. With reference to the speed got in various strata it was interesting to note that in some rocks 1 foot per 5 minutes (12 feet per hour) was attained. In fairly hard sandstone, 6 feet per hour could be got. The lowest speeds were got in fakes and blaes and in the softer metals, only 2 feet per hour being bored.

The bore was plugged to stop an overflow of water, "which, however, was not very heavy."* It was very doubtful whether the overflow mentioned was any indication of the feeders likely to be got in the event of sinking.

Mr. JOHN B. THOMSON (Hamilton) said that, on comparing the rate of boring from the figures given by Mr. Kirkby in his paper with the figures given in his (the speaker's) paper on "A Diamond Hand-boring Machine,"† he found that the rate of boring with the Wilson rig was 5 feet 3¾ inches per shift as compared with 5 feet 2½ inches per shift with the Kyle diamond

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evidently observed with the small motor used. He thought that it was a mistake to introduce a petrol-engine underground: first, because of the smell and the deleterious effect which the gases of combustion had upon the ventilation; and, secondly, because of the inflammability of petrol being a source of danger in causing fires. As to the space taken up by the Wilson rig, it was very much more than that occupied by the diamond hand rig. Sixteen feet was required as against 8 feet, which made a big difference in supporting the roof, especially if it were soft. He also took objection to Mr. Kirkby's remark about the speed of the drill. He thought that 150 revolutions per minute was far too quick for boring with diamonds. A speed of 60 to 80 revolutions per minute was about the average in steam diamond boring.

Mr. Andrew Kyle (Galston) said that he would like to know how many hours Mr. Kirkby regarded as a day. Did they work 8, 12, or 24 hours? Some boring machines worked only 8 hours out of the 24, and others 12 hours, so that when it came to a comparison it was necessary to know whether it was shifts of 8 or 12 hours that was meant.

The President (Dr. R. T. Moore) said that Mr. Kirkby had done them a service in recording in the *Transactions* an account of this application of a petrol-engine to boring. There was no doubt that a diamond hand rig was a very convenient thing, but, at the same time, one always wanted to minimize labour as far as possible. If some light petrol-motor could be adapted for surface work, so as to wind up the rods, etc., it would, no doubt, be found to be an advantage. It was a point that seemed to him to be worthy of the consideration of boring contractors. Boring work had often to be done in awkward places, and a steam-engine was rather a clumsy appliance to take down to where the bore-hole was to be sunk. If one had a light petrol-engine, as light as that used in connection with a motor-car, it would be more easily fixed up and the petrol would be more easily carried about than coal. He had no doubt that there was an opening for something like this which would accelerate the work of boring.

Mr. Sam Mavor (Glasgow) said that for some years petrol-engines had to a considerable extent been in use for pumping in

Australian collieries, and at long distances in-bye; and in Hungary gasolene locomotives were in fairly extensive use underground, the exhaust being directed into a water-tank carried on the locomotive.

Mr. KIRKBY, in replying to the discussion, wrote that he did not take credit for the idea of applying a petrol-motor to drive a diamond drill. That belonged to the contractor who executed the bore, and that was the first instance in which he had applied it. Mr. John B. Thomson was certainly correct in stating that the time was killed in drawing the rods, and if the motor had been applied to that part of the work also, the speed would have been much greater. The writer understood that the same motor was now being arranged for drawing the rods at another bore, the motor being quite powerful enough for the work.

Mr. Thomson had not quite understood the writer as to the size of the place required. The regular width of the place was 10 to 11 feet, with a hole to the side of 5 feet, into which the vertical carriage was drawn. If this road-end had not been there, the carriage could have been drawn the lengthways of the place. Had the motor, too, been arranged to draw the rods, the width required would have only been 7 or 8 feet.

The writer, perhaps, did not make the question of the speed of the drill quite plain. The actual speed was 80 to 100 revolutions per minute, but he wished to point out that where the metals were good, if necessary, 150 revolutions could be got by

[redacted]

NOTE ON TIMBERING ROADWAYS.

By SAM MAVOR.

The preference of colliers to remain in their own districts deprives coal-mining of the advantages of the free and frequent interchange of personnel which is so important a factor in improving practice in other large and similarly widely distributed industries. The consequence is tenacious adherance to local customs and methods. This characteristic of coal-mining has a double disadvantage in respect of (1) persistence of obsolete methods, and (2) lack of the usual vehicles of communication by which minor improvements in practice are disseminated. This second point only need have further reference here.

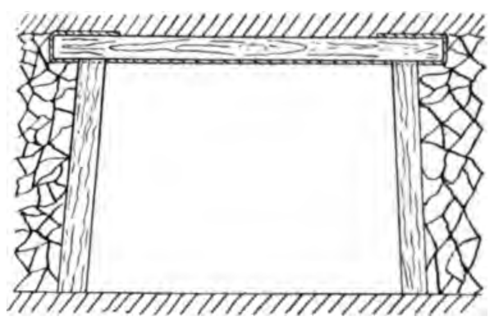

Fig. 1.—Showing a Method of utilizing Old Steel Wire ropes for the Support of Roof timbers.

The actual operations of winning coal, supporting the roof, and forming the roadways, have of necessity been conducted by hand labour, and, subject to modifications effected by coal-cutters and conveyors, must continue to be so conducted. The application of an instrument so flexible in operation as hand labour, under conditions so extremely diverse as those presented in coal-mining, gives wide scope for the exercise of individual initiative and ingenuity, to which many variants of local practice are due. The writer's business gives him exceptional opportunities of intercourse with mining engineers of various districts and countries, and of observing methods peculiar to the localities in which they have originated. The information so acquired is only of

secondary interest to him, but is sometimes, as in the case of the subject of the present note, of sufficient value to warrant its communication.

The method here described of utilizing old steel wire ropes for the support of roof timbers has been in use for some years in Silesia. The rope is laid straight along the underside of the timber, bent over each end, returned 12 or 15 inches along the top at each end, and fixed to the wood by staples, as shown in fig. 1. When in position, the weight due to pressure of the strata holds fast the ends of the rope, so that in tension it becomes an effective support to the timber.

The PRESIDENT (Dr. R. T. Moore) said that it was greatly to the benefit of the members to have new ideas, such as the present one, brought before them. They all knew that wood had a greater crushing than tensile strength, and the wire rope supplied tensile strength to the combination. One would like to know whether there had been any tests to see how much the breaking-strain of the crown was increased by the rope.

Mr. SAM MAVOR (Glasgow) said that his friend had made a sketch showing that if the roof came down and practically broke the timber, the ropes continued to act as a support.

Mr. J. M. RONALDSON (H.M. Inspector of Mines, Glasgow) asked whether the crowns were flat shaped.

[redacted]

somewhat similar to the method that Mr. Mavor had brought before them. In the English translation of the report, unfortunately few details of the system were given. He (Mr. Kerr) thought that it would not be difficult to understand that the strands of these old ropes would get broken very soon, and he would like to ask Mr. Mavor whether he did not consider it a dangerous thing to have broken strands or wires of rope hanging down from the roof. If a man happened to get a scratch with a broken wire of an old rope, blood poisoning might very easily set in, and that was a point which ought not to be lost sight of in the use of old ropes, especially in view of the claims for injury that would be made under the Workmen's Compensation Act, which had added so considerably to the working costs of all mines. Looked at from a practical point of view, would the use of old ropes, in the way described, be of much advantage after all? He (Mr. Kerr) did not think so. The worst roofs were usually those in which water was present, and, under such conditions, old ropes would not be of much advantage for any length of time in assisting the cross timbers or crowns to resist the roof pressure. When water was present, especially if the water contained acids, corrosion would be set up very rapidly in wire ropes; they would soon become brittle, and retain only a small percentage of their original strength; in fact, their breaking-strain might readily be much less than that of a good larch crown. In these circumstances, there was possibly, after all, not a great amount of saving between an old rope and a new crown. He (Mr. Kerr) would certainly not recommend anyone to utilize old ropes, in the way described, in low roads, where workmen would be apt to knock their heads against broken wires, for there was hardly anything so dangerous as rusty broken wires, in underground workings: very small injuries from such a source might lead to very serious consequences. The use of old ropes, as described, might be admissible under certain conditions, such as where there was plenty of head-room and the workings free from water; but, as a rule, the fewer old ropes used in underground workings the better.

Mr. John MacLuckie (Larkhall) said that he did not see how this method could be applicable to a coal-face. According to the figure shown, he could readily see that the system might be tried

in an ordinary drawing-road. In the time spent in adjusting the rope, however, a man would as readily put up another crown. He could not see any economy whatever in the arrangement.

Mr. KERR said that possibly after all there was not a great amount of saving between an old rope and a new crown. It was not the tensile strength that was the objection. In this case, it was the breaking-strain.

Mr. J. M. RONALDSON suggested that someone should make an experiment with an old rope and communicate the results to the members.

Mr. MACLUCKIE said that he would do so, and he hoped to be able to give them some information on the point at the next meeting.

Mr. MAVOR said that he might reply to Mr. MacLuckie by stating that he did not suggest the use of this method at the coal-face. The members of the Institute were the best judges, but it seemed to him that the sphere of application of the system was in the roadways.

The conditions in Hungary in respect of supply of ropes for the purpose indicated were perhaps more favourable than in this country, because winding-ropes there were discarded after a much shorter life than in this country. As an indication of the special attention given to winding-ropes, he might state that the [redacted]

HOW WELDLESS CHAINS ARE MADE.

By ALEXANDER G. STRATHERN.

Historical.—It is now fully fifty years since inventors turned their attention to the manufacture of a chain which would be stronger and more reliable than the ordinary welded chain of commerce.

The frequency with which accidents happen, involving loss of life or serious damage to goods, owing to the sudden breaking of welded-iron chains, has long been a source of worry and anxiety to all who have used such lifting appliances. It is the author's intention to describe the different methods which have been devised to produce a weldless chain, with links resembling in general appearance the ordinary welded crane chain in daily use.

It is now just one hundred years since Robert Flynn, of North Shields, made the first iron-chain cable in this country, so that ordinary iron chains have only been made commercially during the last century. Many improvements in the method of making these chains have been effected, and a most creditable article is now produced by the best manufacturers. It is still acknowledged, however, that the weak spot is the weld in each link.

A few years ago, the United States Board on the Testing of Steel and Iron made tests of 210 lots of chain cables, with the following results:—

1 chain	had a strength	of	85	per cent.	of the	double bar.
21 chains	,,	,,	,, 75 to 85	,,	,,	,,
16 ,,	,,	,,	,, 70 to 75	,,	,,	,,
107 ,,	,,	,,	,, 55 to 70	,,	,,	,,
65 ,,	,,	,,	,, less than 55	,,	,,	,,

This shows that the breaking-strain could not safely be considered as more than that of the single bar, although it is generally assumed that the reduction in strength due to the weld is from 10 to 40 per cent., or an average of 20 per cent. less than the double bar.

Such results as the foregoing have always obtained, and it is consequently not surprising that inventors should have exercised their ingenuity to find a method of manufacture by which stronger material may be used, and such as does not depend almost entirely upon the skill of the workmen.

The first record which we have of a proposal to make weldless chains is due to an American named Sleppy, who obtained a United States patent in the year 1853. The drawings accompanying Sleppy's specification merely show four rollers, with the formation of the chain-links cut on the periphery of each, the intention evidently being to roll the chain from a bar of cruciform section, although no details are given.

We next find, in the year 1858, an application for a British patent in the name of Charles Burn, of Paddington. The title of this invention is, "Improvements in the manufacture of Iron Cables and Chains, and applicable to the manufacture of Gold and Silver Chains." The method described is that of stamping the link-form along the webs of a bar of cross-section, the pitch of the links being marked off along the length of the bar; the bar is then placed on an anvil under the steam hammer, or in the punching-machine, and pieces are punched out first along one web and then along the other, in order to get the link-formation. Another series of punchings is made along the core-portion of the bar, in order to separate the links from each other. This inventor states that all the punching operations may be per-

[redacted]

The partial success attained by Oury appears to have encouraged other inventors, and we find patents following in rapid succession. The next is a communication from France in the year 1883 by the Comtesse de Montebello. This invention relates to a machine for the production of weldless chains from cruciform bars, nearly all the processes being performed simultaneously by different tools as the bar advances. First, there is a set of punches for cutting away portions of the webs of the bar so as to form the outline of the links; the bar is then rocked by means of a cam-sleeve to admit of oblique holes being punched through the core in order to separate the links; then a set of punches come into action to remove the metal from the inner portion of the links, after which forging, rounding, and shaping tools follow. The chain is intended to leave the machine in a completely finished state. Practical experience, however, has shown that it is impossible for all the foregoing operations to be successfully performed in one machine.

Next comes a patent granted in the United States, in 1886, to Maximilian Jacker. The specification describes a rolling mill having four rollers geared to rotate together and being wedge-shaped on the periphery on which the link-forms are cut. A heated bar of cruciform section passed between these rolls would have the links impressed on both webs. The inventor states that the thin web connecting the links together can be removed by placing the chain-bar in a tumbling box. In actual practice, the thin film must first be punched away. This invention did not prove very successful, and nothing is now heard of it.

Two years later. a patent was granted to Julius Kinder, of Brooklyn, for a process of weldless-chain making. Kinder's specification described a very complicated apparatus, in which it was intended to perform all the operations necessary to deliver a completely finished chain at one passage through the machine. It is needless to say that this was attempting too much, and no success attended the proposition.

A much more practical invention was that of M. Rongier, a French engineer, who obtained British patents in 1889 for a process of punching cruciform bars of steel, in the cold state, to produce a weldless chain. By the Rongier process, an excel-

lent chain was produced. A considerable quantity was sold and the chain is now in daily use in many parts of the country.

The method of manufacture was to pass a cruciform bar through a specially constructed punching tool; the punches descended first on the horizontal web, then the bar was rotated to bring the vertical web into the horizontal plane, and fed forward a distance equal to half the pitch of the links, when the punches again descended, and so on throughout the length of the bar. The links were afterwards separated by torsion, and rounded and finished in suitable pressing dies. This process was ultimately discontinued, on account of the limit of size which could be produced and the amount of waste material involved, the scrap punched out being equal in weight to the finished chain.

There is one other system worthy of mention, namely, that of Otto Klatte, a German engineer, who was granted a patent in the year 1892. Klatte's method of producing weldless chains closely resembles those of Sleppy and Jacker, already mentioned, but the rolling mill employed is of a much more substantial and practical design.

There are a few other inventors whose names might be mentioned, but the foregoing account covers the chief points of interest, and gives a fair idea of the proposals made for dealing with a very difficult problem. In all the processes referred to, with the exception of rolling, one serious difficulty presents itself, namely, the separation of the links. If a cruciform bar is stamped or

[redacted]

by the Rongier system. In the first place, it was necessary to devise a method of impressing the link-form on the cruciform bar by a machine which would be moderate in first cost, convenient to work, and constructed in such a way that the pressing dies could be easily and rapidly changed from one size to another; an accurate, automatic feed is also an essential point. The method employed may be termed "segmental rolling" or "stamping." The machine is strongly built, and is placed close to the end of a furnace of the Weardale type. The main frames are of cast-steel, secured to a heavy cast-iron bed-plate. Four crank-shafts rotate in bearings at each corner of the main framing. Each crank actuates a slide working in diagonal guides cast on the frames; these slides carry the die-quadrants pivoted at their inner ends, and to these quadrants the dies are secured. The arc formed by the die-faces is described from a centre considerably to the forward side of the centre of the pivot on which the quadrants rotate. By this arrangement, the dies incline to rotate so soon as pressure is applied by the cranks, and by this means the bar is pressed and fed forward at the same time. The cranks only impart an inward and outward motion to the dies, while the lateral motion is obtained from the eccentricity of the acting faces just referred to. In order to prevent the lateral movement from being too rapid, and so releasing the pressure on the bar, the motion is controlled by a massive cam gear. A hollow shaft is fixed in the centre of the machine, and admits of the stamped bar passing through; sliding on this hollow shaft is a sleeve, connected by links at one end to the quadrants carrying the dies, and pivoted at the opposite end to massive levers, which, in turn, are connected to the cam-gear rotating underneath. The cam face is so constructed that no lateral motion of the dies is permitted until the cranks have advanced the dies right in to the core of the bar. From this point the cam admits of a fixed amount of lateral movement of the dies, while maintaining an even pressure on the bar. When this point in the cycle has been reached, the cranks are just turning the inner centre and the cam rollers are coming into contact with a concentric portion of the cam. The withdrawal of the dies from the bar now takes place, in a straight line, with the outward motion of the cranks. As soon as this is effected, the cam rotates, and the dies return to the

starting point, the bar remaining stationary during this time. The dies are again advanced inwards to impress the next series of links on the bar, and so on throughout its entire length. The dies are adjusted outwards or inwards by means of eccentric bushes on the crank-pins. A worm-wheel is formed on the periphery of each bush, a screw engages with this, and passes through the retaining cap. By turning the screw from the outside, the bush can be rotated, and the thick or thin side brought uppermost as required. An index secured to the cap shows the position of the bush. The gearing is all double-helical cast-steel, and the power is transmitted through an elastic clutch. A water-service is fitted, and so arranged as to cool the dies after each revolution of the machine.

The heating-furnace is 45 feet long, and is supplied with gas from a producer of the Dawson type. The machine makes ten revolutions per minute and stamps 2 feet of the bar at each revolution. This rate of speed gives the metal time to heat during its passage through the furnace, irrespective of the length of the bar. As the bar, which we may now call "the chain-bar," leaves the pressing machine, it rests in a long cast-iron channel, which keeps it perfectly straight until sufficiently cool to be removed to the web-cutting machine. The chain-bar is held rigid by the thin webs of metal surrounding the links. When cool, the chain-bar is passed through a punching machine, actuating punches, which remove the outer and inner webs, the bar being

[redacted]

is then polished bright and smooth in a tumbling-box, and is finally passed through a machine which automatically blocks every link to the same size and shape, so that a pitch chain is the result.

The links are all made with thickened ends, as this is recognized to be the best practice, and adds very considerably to the life of the chain. Prof. Unwin, in speaking of iron chains commonly in use, says:—*

"When a tension is applied to such a chain, each link is subjected to a bending action additional to the tension, the bending being greatest at the extremities of the longer diameter of the link. Hence on purely theoretical grounds the link should be stronger at the ends of the link. On the other hand, it would involve excessive expense to vary the section of the link, and the question of the best theoretical section is complicated by the uncertainty as to the strength of the weld."

It will thus be seen that we are fortunate in being able to produce in actual practice, and without extra cost, the form of link which is theoretically correct according to the above eminent authority.

When a steel chain is made from a cruciform bar, it is necessarily limited to the length which the bar will produce, say from 60 to 90 feet. When greater lengths are required, these may be connected by steel shackles, but it is preferable to use a very fine quality of welding steel for this purpose, and make the connecting link an exact reproduction of the weldless link, with the exception that the thickness is slightly in excess. The steel for the purpose is somewhat expensive, and the workmanship is performed with special care, the result in every case being satisfactory. When a connecting link of this description is used, it is subjected to a severe test which would show any defect in the weld. It is passed through the same dies as those which block the other links of the chain, so that it does not in any way affect the pitch. These connecting links when tested at Lloyd's Proving-house have invariably broken under a load exceeding by 25 per cent. that which would break the chain which they connect.

Although steel only has been mentioned as the material employed in the manufacture of chains by this process, almost any of the bronze alloys can be made into chains in the same manner.

* *Unwin's Elements of Machine Design*, eighteenth edition, page 528.

The strength of weldless-steel chains made by this process exceeds that of welded-iron chains by about 100 per cent. This in itself is a great advantage, as chains of smaller dimension and much less weight may be employed, and a great saving thus effected not only in first cost, but also in handling and stowage. Samples of $\frac{7}{16}$-inch chain tested at Lloyd's Proving-house broke with a load of fully 9 tons, and independent tests of the same size of chain tested at the Sheffield Testing-works broke with a load of nearly $9\frac{1}{4}$ tons, whereas the Admiralty breaking-strain required for a chain of this size is only $4\frac{1}{2}$ tons.

Another great advantage is the allowance made at the ends of the links for wear-and-tear. It is generally acknowledged that steel is a much better wearing material than iron. The greater area provided at the ends of the links admits of a much larger bearing-surface than that which obtains in an ordinary welded chain, and a considerable time must elapse before a weldless-steel chain has been reduced at the ends of the links to the dimensions at which an ordinary chain begins its life. After many years of hard wear, the ends of the links of a weldless-steel chain have been found to be still greater in area than the sides, whereas an ordinary iron chain would have been rendered practically useless, on account of the links having cut into each other and probably reduced the strength of the chain by one-half.

In addition to the foregoing advantages, a weldless-steel chain [redacted]

load of $4\frac{1}{2}$ tons would break the iron chain, whereas an extra load of 9 tons would be required to break a weldless-steel chain.

Weldless-steel chains are used for all general and mining purposes, such as crane chains, pitch chains for driving, cage-bridges, hauling and lashing chains, sling chains, hutch or tub-couplings, tramcar-brake chains, trawlboard chains for steam fishing vessels, steering-gear chains, and, in fact, all purposes for which welded iron chains are used.

In conclusion, it may not be amiss to quote the following from an article on "The Evolution of the Chain,"* by Mr. J. Hartley Wicksteed, an ex-President of the Institution of Mechanical Engineers, who, after describing how weldless chains are made from cruciform bars, writes as follows:—

"If a weldless chain of strong steel comes into use in the near future it will bring about a sudden improvement of 2 to 1 upon the chain that has prevailed for a hundred years—that is to say, it will double the strength, weight for weight. Its development arises from an improvement in mechanical art concurrently with the improved production of steel. The chain of the present suddenly doubled the efficiency of all previous chains. . . . . . . Before that there was no substantial improvement in chain-making for nearly three thousand years. Previously to 1000 B.C. we cannot trace the existence of iron chains at all, yet iron itself must have been known and used in Egypt six thousand years ago. It seems, therefore, to have taken three thousand years with the knowledge of iron to make a beginning with iron chains, then there was little or no improvement for a period of three thousand years, when suddenly the beautiful round section oval-shaped short link chain of Robert Flynn, and the stud link chain of Lieutenant Brown in 1812, made a 2 to 1 improvement on the previous square cornered self-destructive chain, and then, after a period of only a hundred years, we foresee another 2 to 1 improvement." †

Mr. F. Gross (Newcastle-upon-Tyne) said that with his evident intention to be generous towards the iron-welded chains, the author had, to his mind, hardly done full justice to the weldless-steel chains as now made.

Except by some of the actual users of these chains, it was scarcely realized, as yet, what a great difference divided them from the iron chains welded in the usual way—a difference no less than that between the good steel railway-tyre of to-day and the tyre of sixty years ago, made out of an iron bar, bent and welded. Much ingenuity was being displayed in devising various methods of welding links practically limited to iron,

* *Page's Magazine*, 1904, vol. iv., page 99. † *Ibid.*, page 112.

whereas "steel weldless" was naturally the rock-bottom method of manufacture of chains. Steel as a material could readily be produced at the present day, and dealt with so as to give not only double, but even treble, the strength of the same weight of iron, and yet be far safer than any welded chains.

Without intending to be in the slightest degree unfair to iron-welded chains, he might draw attention to the fact that even with this relatively easy material to weld, no man could make one hundred welds all equally good. It was but stating a simple fact, that in every hundred welds there were some much weaker than others; indeed, so weak that at the makers' works and at the proving-houses they broke with less than the proof-load specified by the Board of Trade rules, although the chains were supposed to stand double this load before breaking. All that one could really know about the strength of an iron-welded chain was that it had stood whatever stress it had actually been subjected to in the proof-test, when such had been applied.

To show the great strides made by the weldless-steel chain as now in the market, it was only fair to point out that Mr. Strathern, of his own free will, subjected every one of his chains to double the proof-stress required by the Board of Trade for iron chains of the same size; in other words, he voluntarily tested his chains in the machine to a stress which would certainly break ninety in a hundred of the usual iron-welded long chains, many of them long before they reached this stress. [redacted]

without welds for chain-manufacture would become just as general as it already had for other purposes.

Mr. J. M. RONALDSON (H.M. Inspector of Mines, Glasgow) said that mine-owners would want to know the cost as compared, strength for strength, with another chain.

Mr. A. G. STRATHERN said that there was really no standard by which they could compare prices. They could buy an iron chain at almost any money they cared to name. One maker, for instance, issued a catalogue in which five different brands were specified. Starting with ½-inch chain of the cheapest brand, this was quoted in the catalogue referred to at 26s. per cwt. There were other makers, however, who could supply a chain of the same size at as low a price as 19s. per cwt.

The maker of whom he (Mr. Strathern) was thinking, who quoted his lowest price as 26s. per cwt., quoted the next or "Best" quality at 32s., then followed "Best Best" at 36s., then a "Special Best Best" at 59s., and, after that, there was a "Very Special and Extra Best" at 69s. per cwt. The ½-inch chain quoted at 69s. per cwt. was only equal to the Admiralty standard, or very little over; that meant that the chain would probably break at something under 2 tons. A ½-inch weldless-steel chain, on the other hand, would have a breaking-load of approximately 3 tons; the price would be about the same as that which he had mentioned for the very best iron chain, roughly 69s. If they took into account the fact that they had an increased breaking-strain and also three times, and in some cases four times, the wear, they would see that in the long run by far the cheapest chain was the weldless-steel chain.

It was absolutely necessary, in order to be fair, to take into account all the different brands of iron chain. If they excluded from the comparison of welded-iron chain and weldless-steel chain the strength and wearing properties, they did not do justice to the chains which they were comparing. Another point that occurred to him was this, that no two makers would specify the same quality of chain. They all had their "Best," their "Special Best," and so on. That was no guarantee of the quality at all. One maker's "Best" chain might be another maker's "Treble Best." It all depended on the honesty and the reputation of the manufacturer. When they specified iron chain, they never

really knew what they were getting. If they specified weldless-steel chain, they knew precisely where they were. There was only one quality of weldless-steel chain, and that was of the very highest. There was no such thing as "Best," "Best Best," and so on.

The further discussion of the paper was adjourned.

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY, EDMUND STREET, BIRMINGHAM,
APRIL 13TH, 1908.

MR. ALEXANDER SMITH, PRESIDENT, IN THE CHAIR.

The minutes of the last General and Council Meetings were read and confirmed.

The following gentlemen, having been duly nominated, were elected:—

MEMBERS—
Mr. E. T. BORLASE, Lecturer in Mining, The University, Birmingham.
Mr. W. DAVIES, Lecturer in Mining to the Glamorgan County Council, Aberdare, South Wales.
Mr. GRANVILLE POOLE, Lecturer in Metallurgy, The University, Birmingham.

HAMSTEAD COLLIERY DISASTER.

The PRESIDENT (Mr. Alexander Smith), in moving votes of condolence, said that when at the last meeting of the Institute the members had heard the valuable communications by Prof. Hill* and Mr. W. Charlton,† which had given rise to so excellent a discussion upon life-saving apparatus and rescue-stations, they little anticipated that such a fearful object-lesson as the Hamstead colliery disaster would so soon occur. No local accident had, he thought, caused so much sensation and sympathy, or promoted so much liberality on the part of the public. The whole circumstances were exceptional and peculiar; but, as

* "Breathing-apparatus for Use in Mines," by Prof. Leonard Hill, *Trans. Inst. M.E.*, 1908, vol. xxxv., page 24.

† *Ibid.*, page 37.

they were to form the subject of a Government enquiry, he would not go into them. There were, however, certain things with which they, as a mining institute, at their first following meeting were bound to deal.

First, he must ask them to pass a vote of condolence with the wife and family of the late Joseph Hughes, of Hamstead colliery, who was an associate of the Institute, and, he believed, an excellent under-manager. He was also a very experienced Thick-coal worker, and had lost his life, whilst contending with one of the troublesome spontaneous underground fires, three days before the more serious accident.

At the same time, he (Mr. Smith) knew that it would be their wish to pass a further vote of condolence to the wives and families of those who had lost their lives in the Hamstead colliery disaster, and in this connection he especially included the brave wife and relatives of the hero Welsby. There was no greater deed known to humanity than for a man to lay down his life for others. He was sure that the members, as representing the whole of the mining engineers of the district, sincerely sympathized with the sufferers in that terrible disaster.

The resolution was then carried in silence, the members standing.

The President, continuing, said that he had a somewhat pleasanter duty to perform, and that was to propose a vote of [redacted]

He would also include in his resolution the directors of the Hamstead Colliery Company, who had spared nothing in their anxiety to save the lives of their men; the Government Inspectors of Mines, and notably Mr. Hugh Johnstone, who had given his time, skill, and experience almost night and day in assisting the management; and the management of the colliery, and in this connection he could not speak too highly of the indefatigable work done by Mr. A. W. Grazebrook, their Vice-President and the managing director of the Hamstead Colliery Company; by Mr. M. W. Waterhouse, and by those under them. Mr. Grazebrook had worked night and day, and had never lost sight of the main object of saving the men if possible. Mr. Waterhouse had worked so indefatigably that he had broken down before the end. He had donned a breathing-apparatus (to which he was not accustomed), and had gone into the mine. The difficulties of facing a fire in a mine could not be appreciated by the uninitiated, as the conditions were as dangerous and depressing as it was possible to conceive.

He (Mr. Smith) could not give the names of those who assisted the above gentlemen, as so many tendered their good offices and did so much useful work. There was considerable credit due to the men who performed the dangerous and disagreeable work of restoring the roadways and discovering and bringing out the dead bodies.

The thanks of the members were also due to those who subscribed to the relief-fund, and particularly to Mr. Harvey and the staff of the *Birmingham Daily Mail* for their splendid and adequate assistance. Last, but not least, he must mention the good work of help and consolation rendered to the sufferers by the Salvation Army.

The resolution was put to the meeting and carried unanimously, being briefly acknowledged by Mr. A. W. Grazebrook and Mr. H. Johnstone.

The PRESIDENT referred to the appointment of Prof. R. A. S. Redmayne as Chief Inspector of Mines, and said that every member of the Institute would desire to congratulate him upon that distinction. He took it as a great compliment to the Institute, for Prof. Redmayne had been a very prominent member during his

stay in Birmingham. By his removal, the Birmingham University would sustain a great loss, for he had proved himself an excellent organizer and instructor.

Mr. William Charlton (Walsall) seconded the resolution, which was adopted.

PROPOSED RESCUE-STATION FOR THE SOUTH STAFFORDSHIRE DISTRICT.

The President (Mr. Alexander Smith) said that it would undoubtedly be a very wise precaution to establish in every mining district in the kingdom private rescue-stations, where brigades of miners could be specially drilled and trained in the use of the new life-saving apparatus, so that their services would be available immediately in case of emergency. The last word had not been spoken with regard to these appliances, and in all probability they could be improved or modified. That improvement could only be accomplished by the question being taken up by practical men, and nothing could be done without funds. Several mining centres were now taking action, and it would be necessary to secure the co-operation of coal-owners' associations. He had communicated with Sir Alfred Hickman, Chairman of the Warwickshire Coal-owners' Association; Captain W. B. Harrison, Chairman of the Cannock Chase Coal-owners' Association; and Mr. G. H. Claughton, Chairman of

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station in the district. Previously, when anything happened at the pit-bottom in the way of fires, those at the top were powerless to render any assistance. It was shown at Hamstead colliery that with the special apparatus men were not only able to descend the shaft, but to penetrate the workings for a distance of 1,000 yards. Had the entombed men been nearer the bottom of the shaft, they would probably have been rescued.

Mr. D. E. Parry (Bloxwich) seconded the resolution, which was carried unanimously.

Mr. S. F. Sopwith read the following paper on "An Emergency Pumping-plant at Cannock Chase Colliery":—

AN EMERGENCY PUMPING-PLANT AT CANNOCK CHASE COLLIERY.

By S. F. SOPWITH.

Introduction.—In placing the following notes before the members of the Institute, the author would, at the outset, remind them that, as the title suggests, they are not descriptive of a model pumping-plant, but simply set forth the means taken to deal with a sudden and unexpected feeder of water. He hopes that the practical character of the paper may appeal to the members, and heartily invites that friendly criticism which always adds so greatly to the value of a paper of this nature.

The necessity of pumping arose from the tapping of water whilst proving some disturbed ground in the vicinity of the Eastern Boundary-fault at Cannock Chase colliery. A trial-heading was driven through a downthrow-fault, up to which deep coal was being worked. This heading, after striking the Shallow seam and following it to the dip for some yards, was continued level through the Coal-measures; the Bass seam was intersected, and the Yard seam should shortly have been met

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both of which were sunk originally to the Old Park seam, where some heading-out work was done. In 1894, one shaft (which may be called the main shaft) was sunk to the Shallow seam, and shortly after this did duty as a ventilating shaft for the workings of other pits, the main return-airway being the level shown in the shallow goaf in fig. 1 (plate iv.). This shaft was further sunk to the Deep seam in 1907, and the brick-lining was barely complete before the events recorded in this paper took place.

The second shaft is used for pumping, a feeder of about 35 gallons per minute (mostly from the Five-feet seam) being dealt with. The arrangements are as follows:—A beam condensing-engine has its crank-shaft geared into a second shaft which operates the T-bobs of two Cornish lifts. This second shaft can be thrown out of gear by means of sliding carriages, when required. On the opposite side of the crank-shaft is a shaft on which a winding-drum is mounted, which is thrown in or out of gear in the same way (fig. 2, plate v.). It will, therefore, be understood that if any work is to be done in the main shaft, pumping is brought to a standstill. Moreover, to examine the pumps, change buckets, etc., the winding-rope has to be taken in at one end of the engine-house, slung over, taken out at the other end, and passed over the pulley on the pumping-shaft headgear. Another point to be noted is that no work can be done in the shaft when men are in the workings, as the opening of the doors at the top of the shaft causes the fan to draw its air from the surface instead of through the workings.

The pumps consist of three bucket-lifts: top lift, 171 feet 10½ inches in diameter; middle lift, 102 feet 10 inches in diameter; bottom lift, 183 feet 6 inches in diameter; the sump being 51 feet below the Old Park seam, where a heading 90 feet long connects both shafts. The pump-rods for the latter are attached to those of the second lift. There is a large lodgment just below the Five-feet seam, and it is here that most of the water collects, the lower lift serving only to raise such water as collects in the shaft below this point or leaks from the garlands above; hence it happens that the lower lift is often run on blast long before water is down in the lodgment. The pump makes 9 strokes per minute.

The other surface-arrangements consist of the following:— A pair of 14-inch hauling engines, driving an endless rope, which is carried down the main shaft as far as the Bass inset, and thence round the workings; a Capell fan, exhausting 55,000 to 60,000 cubic feet of air per minute, belt-driven by a steam-engine, and ventilating a large portion of the workings of two other pits; a winding-engine, recently erected, which has not yet been connected to the boilers; and a brick-mill, drying-sheds, and kilns.

Steam is supplied by a range of five egg-ended boilers working at a pressure of 30 pounds per square inch, and separately to the brick-mill engine by a Lancashire boiler capable of working at a pressure of 65 pounds per square inch.

Influx of Water.—2,100 feet of 2½-inch galvanized wrought-iron tubes were immediately ordered to carry the water to the Bass inset at No. 7 pit, a distance of 1,700 feet, having a fall of 75 feet (fig. 3, plate v.), and thence for 270 feet up the shaft to the Old Park level (fig. 2, plate v.). The next step was to attempt to dam off the water, the broken nature of the strata, however, being such as to render the success of this step very doubtful. The best position being selected, a 3-foot dam of concave shape was built with bricks set in cement, having both horizontal and vertical joints broken. The rock in front of this was meanwhile prepared for a second similar dam, the space between being filled with puddled clay. A ¾-inch air-pipe was built

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Steam Pump.—The aspect of affairs being now really serious, steps were at once taken to conduct the water into old workings, whilst the respective merits of a rope-driven or a steam pump were considered as the best means of relieving immediately the situation. Both had their objections, but the fact of having to detach all tubs and run the hauling-rope continuously weighed greatly against the former method, as also the extra work and delay entailed in fixing: consequently it was ruled out, and a steam pump was determined upon. It may be well to point out here that with some 50,000 to 60,000 gallons of water per day running into old goaf of limited area, the main consideration was to do something at once, if only of a temporary kind, and decide afterwards with respect to a permanent plant. A steam pump 10 by 5 by 12 inches was procured from Messrs. Joseph Evans and Sons, capable, with 40 pounds of steam-pressure, of raising from 80 to 100 gallons of water against a head of 270 feet. This was lowered down No. 7 shaft, and was at work on November 12th, 1907, the 1½-inch pipes put in for the hydraulic pump being utilized, for the time being, as a steam-main. These were extended as far as the brickworks boiler, the only one capable of raising steam at sufficient pressure. Steam-piping, 1½ inches in diameter, was, of course, too small to be thought of as really effective. The actual result was, however, worse than anticipated, namely:—steam on boiler, 65 pounds; steam at pump, 28 pounds; speed of pump required, 100 strokes; actual speed obtained, 9 to 13 strokes, increasing, when the fan was stopped, to 30 to 40 strokes.

Electric Pump.—To get full satisfaction out of the steam pump, it would be necessary to increase the size of both the steam- and the delivery-pipes, but then the lower 6-inch lift of the Cornish pump could barely have dealt with the full quantity, even if it had worked without cessation, a point which, in the call for immediate action, had been overlooked; and though possibly a mistake was made in not replacing the steam-pipes with larger ones, in order at least to pump as much as could be dealt with, yet this would have meant two or three nights' work, and then at best would have been only a makeshift. Therefore it was decided to leave matters as they were, and try at once to get an electrically-driven pump to raise the water to the surface and thus be independent of the lift-pump altogether. This was easily

thought of, but to obtain a pump capable of lifting against the head (750 feet) from stock was another matter. Several makers were tried, and at last a suitable pump, of the Oddie-Barclay differential high-speed type, capable of raising up to 100 gallons at 200 revolutions a minute, was obtained from Messrs. Andrew Barclay, Sons & Company, Limited, of Kilmarnock. A suitable motor was obtained from the Brush Electric Engineering Company, somewhat larger than absolutely necessary, but of a convenient voltage, namely, 460.

There being only one direct-current electric generator of 50 kilowatts capacity working at 500 volts at No. 3 pit, $1\frac{1}{2}$ miles away, running $5\frac{1}{2}$ hours a day, the question of putting up a temporary plant at No. 7 pit, or transmitting the power from No. 3 pit had been meanwhile considered, and the conclusion arrived at that, owing to the fact that over 7 miles of No. 3 standard wire-gauge copper wire had just been delivered on account of a proposed electric scheme for the colliery, the latter proposition would come out cheapest. About 5 miles of wire were actually used, and carried on large double-shed insulators fixed on oaken cross-arms bolted to Norway poles placed 120 feet apart, two wires being carried on both the positive and the negative sides. Short lengths of insulated $\frac{19}{16}$ cable connected these to the dynamo switchboard and similarly at No. 7 pit to two Bates fuses fixed in the pumping engine-house at the surface; thence $\frac{19}{16}$ insulated cable (previously in use at another plant) connected to

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mind, the direct connection of the pump-suction to the 2½-inch pipes. The position was this:—Water should flow in 1,700 feet of 2½-inch pipes with a fall of 75 feet at about 63 gallons per minute, which, with the vacuum created at the pump-suction (say 13 pounds), would be increased to about 88 gallons in all. The pulleys had been made to give 150 revolutions per minute, and at this speed the pump should deliver 75 gallons.

Pumping Operations.—A start was made on December 9th, 1907, water being pumped to the surface, certainly, but in intermittent bursts; in fact, the pipes were full of air, and the noise and rattle made threatened to bring them down the shaft. The suction was then connected by 5-inch pipes to a well 6 feet in diameter and 20 feet deep, used for the balance-weights of the hauling-rope tension-slide to hang in, and the 2½-inch pipes were extended to flow into it. When this was done, another start was made, but without success, showing it was not the direct connection to the 2½-inch pipes which had been the source of trouble before. After completely overhauling the pump, it was finally discovered that the fault was, first, in a defective joint-ring in the pump and, secondly, in the setting of the suction-valve, which in this pump is mechanically operated. Another trial was made, and all went smoothly for half-an-hour, when the joints began to fail in the rising-main. These were all re-made, and it was decided to connect by means of a T-piece into the middle lodgment of the Cornish pump, thus taking off a pressure of 100 pounds per square inch on the pipes, and run no further risk by trying to pump to the surface until stronger pipes could be obtained.

Results.—Pumping has been in operation under these conditions ever since without a hitch. One curious point is that although the pump actually runs at 163 revolutions per minute, and at this rate should pump 80 gallons,* careful measurement shows only 64 to 66 gallons per minute, and this almost exactly balances the flow from the 2½-inch pipes, so that a full 8-hour shift could be run without a stop, the pump only gaining very slightly on the flow from the pipes. Pumping takes place

* It is only fair to the makers to state in this connection that they had specified 6-inch suction-pipes; but, owing to space, it was impossible to put in larger than 5-inch pipes, and to this, no doubt, the decreased duty is owing.—S.F.S.

during two shifts of 8 hours each, with 4-hour intervals, when the dynamo is used for pumping at No. 3 pit. The actual hours pumped per day are 13½. The present arrangement will serve excellently until ample lodge-room has been prepared at the pump for holding a 24 hours' supply of water. The speed of the pump can then be increased, and the hours of pumping arranged at more convenient times.

To return to the point when water burst through the dam: the natural flow of the water would have been down the main haulage-road crossing the engine-plane at B (fig. 1, plate iv.) and thence into Old Deep workings at Y. In doing this, however, the engine-plane at B, which lies in a valley, would have been swamped, so a bore-hole was made at X into a road below and a 2-inch pipe inserted. The water was carried by this into the Old Shallow goaf shown on the plan (fig. 1, plate iv.). The lowest point in the Old Shallow level is at V, and the water gradually rose until there remained only a few inches between its surface and the roof. Pipes were now laid from X across the engine-plane to Y, and the water was allowed to run into the Deep goaf there, the bore-hole to the Old Shallow goaf being stopped. The water gradually subsided in the Old Shallow goaf, and ventilation, which had been seriously impeded, was restored. It may be mentioned that this Old Shallow level formed the return-airway for the Deep and Shallow workings in this district. After a few days, the Deep goaf filled, and water began to run over the fault

[redacted]

work was not stopped at all in the No. 1 East District, with the exception of two stalls for about a week. On more than one occasion, coal was being brought round the turn at B (fig. 1, plate iv.) with water halfway up the body of the tub.

Steps are now being taken to fix the new rising-main in No. 7 shaft, which will consist of 5½-inch (external diameter) wrought-iron tubes of specially strong construction, fitted with loose cast-steel flanges, and cut into 9-foot lengths, to facilitate fixing behind the stays, which are from 11 to 12 feet apart. It may be asked why in the first place 4-inch pipes were put in. This was on account of the impossibility of getting pipes of larger diameter behind the stays when in the long random lengths in which such pipes are always supplied, unless made to order.

A properly equipped pumping-room has been excavated, and is being lined with brickwork; while a lodge-room for a 24 hours' supply of water is in course of excavation. When these preparations are complete, the pump and motor will be moved to their new position, where they will be firmly bedded on solid brickwork foundations. The pump will then work under much better conditions, and there is little doubt that it will accomplish all that is claimed for it.

A hearty vote of thanks was accorded to Mr. Sopwith for his paper, and the discussion thereof was deferred.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
APRIL 11TH, 1908.

MR. JOHN H. MERIVALE, PRESIDENT, IN THE CHAIR.

The ACTING SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 28th and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—
Mr. JOHN NORTON GRIFFITHS, Consulting Engineer, 62, London Wall, London, E.C.

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DISCUSSION OF MR. H. W. G. HALBAUM'S PAPER ON "CAST-IRON TUBBING: WHAT IS ITS RATIONAL FORMULA?"* AND OF DR. JOHN MORROW'S PAPER ON "THE STRENGTH OF CAST-IRON TUBBING FOR DEEP SHAFTS."†

Mr. H. W. G. HALBAUM (Horden) wrote that he regretted that temporary pressure of work prevented his dealing fully at that moment with Dr. Morrow's reply, but he would assuredly do so at no very distant date. In the meantime, he would direct particular attention to the significant fact that, in the reply referred to,‡ Dr. Morrow had practically withdrawn his "plate-formula," just as Prof. Galloway had already repudiated the French formula saddled upon him by Prof. Louis, and just as Prof. Louis himself had quietly thrown aside the formula for p, given by him (Prof. Louis) in *Practical Coal-mining*.§

Those early tangible results of his (Mr. Halbaum's) criticisms effectively disposed of Prof. Louis' assertion that there had been no need for him (Mr. Halbaum) to trouble about "the simple case of the plain cylinder." It would be subsequently shown that almost the whole of the remaining positions held by Prof. Louis and Dr. Morrow were equally untenable.

As for Prof. Galloway's rejoinder,‖ he (Mr. Halbaum) had much pleasure in accepting that gentleman's explanations. He would merely point out with regard to paragraph (3)¶ that, by Prof. Louis' account, R was fixed by the formula as one-third of the ultimate stress, whereas Prof. Galloway implied that the engineer might take it at one-tenth if he thought fit. Was not that amending the formula further? With reference to paragraph (7), that gentleman's formula, as defined by himself, was simply the "thin"-cylinder formula for external pressures, stated in terms of the inside radius. His (Mr. Halbaum's) rational formula, on the other hand, was rational for the tubbing case, simply because it gave the thicknesses equal to those, or slightly more than equal to those, which would be obtained by the strictly rational thick-cylinder formula independently

* *Trans. Inst. M. E.*, 1907, vol. xxxiii., page 567.

† *Ibid.*, 1907, vol. xxxiv., page 100. ‡ *Ibid.*, 1908, vol. xxxv., page 70.

§ 1 07, divisional-volume i., page 137.

‖ *Trans. Inst. M. E.*, 1908, vol. xxxv., page 51.

¶ *Ibid.*, page 52.

deduced in the third appendix of his (Mr. Halbaum's) paper.* If Prof. Galloway still thought the two rules similar, he (Mr. Halbaum) would suggest that he should test them by finding the thicknesses given by each when, say, $\frac{f}{p} = 4$.

DISCUSSION OF MESSRS. J. W. FRYAR AND ROBERT CLIVE'S PAPER ON "THE SINKING OF BENTLEY COLLIERY."†

Mr. Frank Coulson (Durham) asked whether the tubbing put in at Bentley colliery was faced and bolted together with drilled holes and properly turned bolts countersunk with lead and steel weazes, in a similar manner to that adopted by German mining engineers. It seemed to him that on one or two occasions the piles were driven too far in advance of the guard-ring at the bottom, and the piles were, in consequence, bent in. He would like to know whether it would not have been an advantage to drive the piles a shorter distance ahead. In the case of wooden piles, the practice was to drive them in a little distance and then clear the way for each pile, and also prevent, as far as possible, sand getting in. At Bentley colliery there appeared to be more sand drawn from the pit than was necessary. He had had the privilege of seeing the system of piling adopted there, and he thought it by far superior to any other that he had seen. If there was any mistake, [redacted]

in forcing the piles down. If the weight had been kept clear away from the pit, there would not have been the same amount of sand to draw out. In the case of sinking the second pit, he took it that the whole of the water would be drained out of the sand, and it would be a comparatively easy operation.

Prof. HENRY LOUIS (Newcastle-upon-Tyne), referring to the Flottmann drill, asked what were its dimensions, and how it was supported: was it a hand-held drill, or was it supported on a tripod or bar?

Mr. J. W. FRYAR (Bentley) agreed that in the sinking of the first pit the piles were put too far in front of the floating-ring, but it must be borne in mind that they had to obtain their experience at this pit. In the second pit, and in the later part of the first pit, the piles were pushed not an inch further out than was necessary to keep the bottom of the pit quiet. Indeed, they were obliged to put them further out in the case of the first pit, because of the boiling up of the water from the stonehead, which was much more violent than in the second pit, where it had not nearly so much force. The pit was wet all the time that they were sinking, and in a great many places the sand, which was of the consistency of mud, had to be filled into buckets.

With regard to the tubbing, as stated in the paper, the outer tubbing was 23 inches in diameter, and there was also an inner tubbing; the outer tubbing, which was put in following the piles, was simply bolted together, with wooden sheeting in between. The water always came in at the bottom, and when they got down it came in all round about the piles, partly from the sheeting where it was jointed, and through the bolt-holes; but they experienced no great difficulty with that, because as soon as they got to the crib-bed the permanent tubbing was put inside and sealed off in the ordinary way, filling up between the two tubbings. They had to go more upon the strength than anything else. It was satisfactory to know that they had last Saturday got down to the coal and obtained a good seam, about 9 feet 3 inches thick, which would amply repay the expense and trouble involved in the initial difficulties of dealing with the quicksand.

The Flottmann drill was a very small drill, not much larger than the ordinary Boyer hammer. It was only about 1 foot 9

inches or 2 feet in length, and 3 or $3\frac{1}{2}$ inches in diameter. It was certainly the best mining drill for sinking pits that he had come across, as in working it was only necessary to couple a flexible pipe on to it. They carried these flexible pipes down the sides of the shaft, with absolutely no machinery in the pit-bottom; a man simply coupled it on and held the drill in one hand, and it would go steadily down—indeed, after about 12 or 18 inches it would even go by itself. After the sumper-holes were drilled, a man could get round the side and have all the side-holes drilled during the time that the sumper-hole was cleared.

In reply to questions by Prof. Louis and Mr. W. C. Blackett, Mr. Fryar further said that the depth of the hole drilled was about 7 feet; and that the drill would go best in hard stone; it did not go at all well in soft shale or fire-clay, but it went very well indeed in limestone.

Mr. COULSON asked whether these drills would work equally well in damp ground. He should imagine that they would work better in very wet or very dry ground, than in ground which contained a little moisture.

Mr. FRYAR said that in using the drill they generally kept the hole filled with water.

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MEMOIR OF MARTIN WALTON BROWN.

By H. F. BULMAN.

Martin Walton Brown was born in Newcastle-upon-Tyne on June 12th, 1854. He was the only child of William Brown, a flour-merchant, and the last tenant of the old mill in Jesmond Dene.

Walton Brown commenced his education in his native city, at the celebrated Percy Street Academy of the late Rev. Dr. J. Collingwood Bruce, where many wellknown north-countrymen were educated, and was afterwards at Dr. Dyson's school at Bradford, Yorkshire. In 1871, he obtained by examination one of four open exhibitions at the Newcastle College of Physical Science (now Armstrong College), of which he was one of the original students, the College having just been founded in that year. He attended the lectures during the session 1871-1872, and obtained a prize in geology. His attendance was co-temporary with the first year of his apprenticeship as a mining student, which he served with the late Mr. S. C. Crone at the Killingworth and other Northumberland collieries belonging to Messrs. John Bowes and Partners, Limited. The period of his apprenticeship (1871-1874) was one of unprecedented prosperity in the British coal-trade, and considerable developments, including three new sinking-shafts, were proceeding at the collieries under Mr. Crone's charge. Altogether, there was ample opportunity for a keen student, like young Walton Brown, to gain a wide experience in practical colliery work.

In those early days, at the age of 20, he showed his natural bent towards literary work, and was already writing articles for the mining journals. He was especially interested in mine ventilation, a subject on which, in later years, he was a recognized authority. It was probably his uncle, the late Mr. J. J. Atkinson (H.M. Inspector of Mines), who directed his attention to this subject, as Mr. Atkinson was the first in England to set out clearly the laws that govern mine-ventilation.

Walton Brown had also grasped the fact that much valuable information may be obtained from foreign sources. He had learnt French, and used to study the *Annales des Mines* and the publications of the Société de l'Industrie Minérale. Later on, he learned German, and thus kept himself informed of Continental progress in mining.

After completing his four years' apprenticeship at Killingworth, he went to Hamsteels colliery, near Durham, as assistant to the late Mr. R. S. Johnson, the managing owner, and whilst there, in 1876, he passed the examination for and obtained a first-class colliery manager's certificate. He spent three years at Hamsteels, leaving to take up a position as assistant to the late Mr. E. F. Boyd, of Moor House, Leamside, County Durham.

Mr. Boyd was the mining agent for the Ecclesiastical Commissioners (Durham Chapter Estates), and for many other coal-lessors, and the work of his assistants consisted largely in visiting collieries all over the county to obtain the account of coal worked, and to put up tracings of the working-plans. It was Mr. Boyd's rule that whenever an account was got, a visit should be paid underground to inspect the workings and take sections of the seam. His assistants, therefore, besides gaining an insight into tentale accounts and coal-leases, saw a good deal of colliery work.

Mr. Boyd had a high opinion of Walton Brown's capabilities, and it was owing, no doubt, to his recommendation, and to that of Mr. R. S. Johnson, that in 1880 he obtained the appointment,

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vious cases and decisions, and the ready way in which he could bring forward information required for the guidance of the Committees.

His association with The North of England Institute of Mining and Mechanical Engineers began in 1871, when he joined it as a student. He was, in 1887, elected a member of the Council, and, in 1891, on the retirement of Prof. G. A. L. Lebour, was appointed Secretary. In the same year, he was also appointed Secretary to The Institution of Mining Engineers. The federation of the Mining Institutes dates from 1889, but Volume I. of the *Transactions* for the year 1889-1890 was not published until 1892, and bears his name as Secretary and Editor. The success of the Institution has been largely due to the work, the care, and the attention which he ungrudgingly gave to its affairs. The admirable character of the *Transactions*, and his merits as Editor, were recognized by the International Jury of Awards of the Louisiana Purchase Exposition, 1904, when they awarded a gold medal to the Institution and a silver medal to Walton Brown.

He made his first contribution to the *Transactions* of The North of England Institute of Mining and Mechanical Engineers in 1882 with a translation from the *Annales des Mines* of "Remarks by Mr. E. Mallard on Mr. Lindsay Wood's 'Experiments showing the Pressure of Gas in the Solid Coal.'"

In 1884, he brought before the Institute the question of the possible connection between earth-tremors and the issue of gas in mines; and a committee was subsequently appointed to investigate the matter, a seismograph and other apparatus being established at Marsden colliery in the autumn of 1886, by the permission of the late Mr. John Daglish. Walton Brown took a leading part in the investigations, and the report of the Committee was published in 1887.

He acted as Secretary to the Committee appointed to enquire into the explosion of an air-receiver at Ryhope colliery, and he drew up the report published in 1888. He contributed a valuable paper on the Correlation of the Coal-seams of the Carboniferous Formation of the North of England—a paper which must have entailed much study and investigation. In it he advanced a quite original theory of the formation of the coal-seams, which he states as follows:—"From a full consideration of the relative

positions of the coal-seams in the true measures, it appears possible that they should be considered as portions of one and the same seam which was in continuous formation during a long period of time. If this theory be based upon fact, the Coal-measures must be then considered as one seam of coal, with intercalated bands or beds of sandstone, shale, and other rocks."*

He was an active member of the Flameless Explosives Committee appointed on March 31st, 1888; and during 1890, in conjunction with the late Mr. W. J. Bird, he translated the valuable and lengthy *Report of the (French) Commission on the Use of Explosives in the Presence of Fire-damp in Mines.*

In 1888, The North of England Institute of Mining and Mechanical Engineers, in conjunction with the Midland Institute of Mining, Civil and Mechanical Engineers and the South Wales Institute of Engineers, appointed a Committee to conduct experiments and report on mechanical ventilators. Walton Brown took a very active part in the work of this Committee, and drew up the valuable and exhaustive report printed by The Institution of Mining Engineers in 1899.† Few men knew more about fans and mine-ventilation than he did, and many of the papers which he contributed to the *Transactions* and to other publications deal with this subject.

A complete list of the papers contributed by Walton Brown to the *Transactions* of The North of England Institute of Mining and Mechanical Engineers and of The Institution of Mining [redacted]

"On a Form of Apparatus for the Rapid Determination of Specific Gravities of Bodies," *Trans. N. E. Inst.*, 1887, vol. xxxvi., page 95.

"A Further Attempt for the Correlation of the Coal-seams of the Carboniferous Formation of the North of England, with some Notes upon the Probable Duration of the Coal-field," *ibid.*, 1887, vol. xxxvii., page 3.

"Report of the Committee appointed to inquire into the Observations of Earth-tremors, with the view of Determining their Connection (if any) with the issue of Gas in Mines," *ibid.*, 1887, vol. xxxvii., page 55.

"Mechanical Ventilators: Observations to be made and Instructions to the Engineers," *ibid.*, 1888, vol. xxxvii., page 189.

"Report of the Committee Appointed to enquire into the Explosion of an Air-receiver at Ryhope Colliery," *ibid.*, 1888, vol. xxxvii., page 197.

"The Pieler Spirit-lamp as a Fire-damp Indicator," *ibid.*, 1889, vol. xxxviii., page 177.

"Experiments with Explosives used in Mines," *Trans. Inst. M. E.*, 1890, vol. ii., page 49.

"Experiments with Carbonite" (in conjunction with the late William Foggin), *ibid.*, 1890, vol. ii. page 85.

"The Waddle Patent (1890) Fan," *ibid.*, 1891, vol. ii., page 173.

"The Lee Alarm Water-gauge," *ibid.*, 1891, vol. iii., page 128.

"The Roberts Shot-firing Lamp," *ibid.*, 1891, vol. iii., page 129.

"The Rateau Ventilator," *ibid.*, 1892, vol. iii., page 410.

"The König Differential Water-gauge," *ibid.*, 1892, vol. iii., page 452.

"The Veitch-Wilson Improved Lamp-pricker," *ibid.*, 1893, vol. vi., page 448.

"The Equipment of Exploring Expeditions," *ibid.*, 1898, vol. xv., page 443.

"Mechanical Ventilators: Report of the Committee of The North of England Institute of Mining and Mechanical Engineers, and the Midland Institute of Mining, Civil and Mechanical Engineers," *ibid.*, 1899, vol. xvii., page 482.

"Newcomen Engines," *ibid.*, 1901, vol. xxii., page 663.

"Memoir of the late John Daglish," *ibid.*, 1907, vol. xxxiii., page 201.

In addition to the above, he also prepared the "Barometer, Thermometer, Etc., Readings" for the years 1888 to 1905 inclusive.

In 1890, he became Secretary to the Board for Examinations for the Newcastle-upon-Tyne Mining District. He maintained his connection with Armstrong College in later years, when he was resident in Newcastle-upon-Tyne, and in 1898 was one of the founders of the Old Students' Union, acting as Treasurer until his death. He was President of the Union during the years 1898, 1899, and 1900, and again in 1907. He sometimes gave the lectures on mining at the College in the absence of the Professor of Mining.

Owing to the position which he held in the mining world, and to his wide acquaintance with all sorts of mining people,

he was frequently applied to in connection with mining appointments, especially abroad. Many men in various parts of the world owe their positions to his recommendation and advice, given freely and gratuitously. He was singularly free from mercenary motives.

His office in Newcastle-upon-Tyne was invaded by numerous visitors, to such an extent as sometimes to interfere seriously with his duties; and, in consequence, much of his work was done at home in the evenings, where he was free from interruptions. His stores of information on mining matters were always at the service of his friends, and his readiness to help others sprang from real kindliness and human sympathy.

He was essentially a robust individuality, with a large share of the sturdy independence, the dogged persistence, and the hard-headedness, which are prominent characteristics of many Northumbrians. He had his own way of doing things, from which he was not easily moved.

A comical instance of his original turn of mind may be mentioned. On one occasion, in his student days, he actually had a photograph taken of the back of his head—what he called a "back elevation"—as he did not see why photographs should be confined to "front views."

His manner did not always convey a right impression of his real nature; and the high compliment may be paid him that he was most liked and appreciated by those who knew him best.

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ship and income; for in 1891, the membership was 670 and the income £1,590, whilst in 1907, the number of members was 1,307 and the income £2,928.

The thirty-three volumes of the *Transactions* issued during his secretaryship of The Institution of Mining Engineers, and edited by him, are a lasting monument to his memory.

In 1885, he married Isabella, daughter of the late John Chrystal, of Lumley, County Durham, who survives him together with a son and daughter. He died suddenly at his residence, in Newcastle-upon-Tyne, on November 22nd, 1907, in his 54th year, and was buried at Jesmond Old Cemetery, Newcastle-upon-Tyne. The large number of people present at the funeral, including representatives of most of the important mining institutes and associations of the United Kingdom, testified to the esteem in which he was held and to the regret felt at the loss which the mining world had sustained.

On the motion of Mr. W. C. Blackett, seconded by Mr. T. E. Forster, a vote of thanks was accorded to Mr. Bulman for his memoir.

Mr. Lawrence Austin's description of the "Demonstration of Rescue-apparatus, Felling, August 31st, 1907," was read as follows:—

DEMONSTRATION OF RESCUE-APPARATUS, FELLING, AUGUST 31st, 1907.

Compiled by LAWRENCE AUSTIN.

An experimental gallery (figs. 1 and 2, plate vii.), 170 feet long, had been erected by Mr. C. B. Palmer, the conditions resembling, as nearly as possible, those that might be met with in a thin coal-seam after an explosion. One side of the gallery was of wire-netting, so that the movements of the wearers of the various apparatus were in full view of those witnessing the demonstration. It was so arranged that narrow and obstructed roadways had to be contended with, piles of débris surmounted, passages cleared through falls of stone, and other obstacles negotiated. A chamber, to be filled with both carbonic acid and sulphur-dioxide fumes, had also been constructed, into which the wearers of the apparatus were to enter.

A programme of the various tests to which each apparatus would be submitted had been drawn up, as follows:—

Each apparatus to be explained, five minutes being allowed for such explanation.

The weight of each apparatus and of the wearer to be recorded, and the men [redacted]

Five makes of apparatus, namely, the Aerolith, Dræger (helmet and mouthpiece types), Fleuss-Siebe-Gorman, Weg, and Westphalia (helmet and mouthpiece types), took part in the demonstration, a short description of each being as follows:—

Aerolith.—The Aerolith apparatus (figs. 3, 4, and 5, plate viii.) utilizes the principle of liquid air evaporating into about 800 times its own volume of breathable air, and has already been described at length in a paper read by Mr. Otto Simonis to the members some time ago.* The apparatus when fully charged will allow of about three hours' work.

Dræger.—The Dræger apparatus (figs. 6, 7, 8, 9, and 10, plate viii.) is of the type employing compressed oxygen, and can be worn either with smoke-helmet and breathing-bag or with a mouthpiece, eye-glasses, and nose-clip, and a similar breathing-bag; the same back-apparatus being used in each case. The back-apparatus comprises the carrying-frame and shoulder-straps, oxygen cylinders, gauge, and pressure-reducing valve with injector, the surface-cooler, and the regenerating cartridges. The oxygen-cylinders, which have each a capacity of 7,320 cubic inches (120 litres), should be charged to a pressure of 125 atmospheres, and the reducing-valve allows of a regular supply of 122 cubic inches (2 litres) of air per minute. The regenerating cartridges are the means of effecting a radical absorption of the carbonic acid in the expired air, and are an important feature of the apparatus. Two flexible tubes connect the back-apparatus with either the smoke-helmet and breathing-bag or with the mouthpiece and breathing-bag. The smoke-helmet is so constructed as to fit the face of any wearer, a pneumatic cushion, inflated by an air-pump attached to the apparatus, forming an airtight joint between the helmet and face, this at the same time relieving undue pressure of the helmet on the head of the wearer. A mica window, of such a size as to allow a wide range of view, in all directions, is fitted in a favourable position, and an air-valve is provided, this being kept open until the noxious zone is reached and a saving of oxygen thus effected. The mouthpiece, made of rubber, is quite comfortable, and cannot easily slip out of the mouth; the closing of the nostrils being effected by means of a nose-bag

* "Liquid Air and its Use in Rescue-apparatus," by Mr. Otto Simonis, *Trans. Inst. M. E.*, 1906, vol. xxxii., page 534.

with screw-clasp, held in position by means of a head-band. The breathing-bag, fastened to the chest by two shoulder-straps and a waistband, is connected either to the smoke-helmet or to the mouthpiece by two flexible tubes, one for the fresh and the other for the expired air, with, of course, two breathing-valves. The whole bag can be easily taken to pieces for cleansing and disinfecting purposes. Circulation is effected by the injector which, using the live power of the compressed oxygen, sucks the expired air from the smoke-helmet or mouthpiece, respectively, into the exhalation-bag and thence through the regenerating cartridges. After passing through the cartridges, the air, which, owing to the chemical action, has become warm, flows through the surface-cooler and receiving a fresh supply of oxygen is reinhaled. The breathing-bag is provided with a safety-valve, which opens automatically, when the bag becomes too full of air, owing to the quantity used being small. The apparatus, when fully charged, will allow of about two hours' work, it being necessary to employ a triple cylinder should a longer period of work be required.

Fleuss-Siebe-Gorman.—The Fleuss-Siebe-Gorman apparatus* (figs. 11, 12, 13, 14, and 15, plate ix.) is also of the type employing compressed oxygen and can be worn with mouthpiece, eye-glasses, and nose-clip; with a half-mask, which covers nose and mouth, and eye-glasses; or with a complete mask, covering nose, mouth, and eyes. The whole apparatus hangs from shoulder-straps, and

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bag and regenerating chamber form the front portion of the apparatus, being connected with the back portion by a flexible tube, and are of such a capacity as to yield an ample volume of air. The regenerating or caustic-potash or caustic-soda chamber is of vulcanized indiarubber, with a protective covering of canvas, and has exhaling and inhaling divisions to ensure the passage of all exhaled breath through the regenerator, before receiving its supply of fresh oxygen for reinhalation. The caustic potash or caustic soda is placed in such a position that, with each movement of the wearer when walking, the carbonated surface is automatically rubbed off, a fresh surface thus being constantly exposed for the absorption of the carbonic acid gas. The breathing-bag carries a relief-valve, allowing for the escape of oxygen should the bag become too full. The respective headpiece is connected to the breathing-bag by two strong flexible corrugated tubes, the end of one tube carrying the inhalation-valve, the other the exhalation-valve, these being of special metal and very light. The rubber mouthpiece is fitted with a small outer rubber band overcoming the danger of its slipping from the mouth or of possible leakage through it—the nose-clip used in conjunction with the mouthpiece being provided with a device which prevents the possibility of its being inadvertently knocked off. Both the half- and complete-masks are provided with a pneumatic interior ensuring an airtight connection with the face of the wearer. The apparatus, fully charged, allows of about two hours' work.

Weg.—The Weg apparatus (figs. 16, 17, and 18, plate ix.) has already been very fully described in the *Transactions*,* but the present apparatus embodies considerable alterations and improvements. The whole of the apparatus is attached to a jacket, made of moleskin or other strong material, the weight of the apparatus being thus distributed over the shoulders and other parts of the body. The oxygen-cylinders, curved to fit the body, and attached to the jacket above the hips, are coupled together by a copper-pipe, and are charged to a pressure of 120 atmospheres, their capacity, under this pressure, being 9,150 cubic inches (150 litres). A pressure-gauge advises the wearer of the pressure that he is using and

* "A New Apparatus for Rescue-work in Mines," by Mr. W. E. Garforth, *Trans. Inst. M. E.*, 1906, vol. xxxi., page 625.

the quantity of oxygen remaining in the cylinder. The combined reducing and "lung-governing valve" forms one of the principal features of the apparatus; it allows the oxygen to pass as it is required, being operated by the intermittent action of the lungs. A bye-pass to the valve is fitted as a precaution, in case the valve were to fail to act. The oxygen passing through an inhalation-valve travels through a copper pipe to the mouthpiece, which covers both nose and mouth and is provided with a pneumatic lining, allowing of a perfect fit to the face. The mouthpiece is fastened to an ordinary miners' leather cap, being held in position by the inhalation and exhalation-pipes which are carried over the head to the regenerator. An elastic strap attached to each side of the mouthpiece, and buckled to a leather flap at the back of the cap, forms an additional safeguard. The inhalation- and exhalation-pipes, carrying valves, are in the form of a square twin pipe until they reach the back of the head where they branch off, in the form of flexible corrugated pipes, to the regenerator. The regenerator, containing caustic potash or caustic soda, is in the form of a curved rectangular metal case, and is carried on the back, and the vitiated air, after passing through it, enters a pure rubber reservoir-bag, attached to the inside of the lower portion of the jacket, whence it travels by the inhalation pipe to the mouthpiece. A small telephone is fitted to the apparatus, enabling the wearer to communicate with rescuers outside the noxious zone. The apparatus, when fully charged, [redacted]

jector through a flexible tube, carried under the right arm to the inhaling-bag and thence to the mouthpiece. The exhaled air passes to the exhaling-bag and regenerator, a rectangular curved metal case, and thence through a flexible pipe, carried under the left arm to the injector-junction, where it mingles with the fresh oxygen for re-inhalation. A blow-off valve is provided just after the reducing-valve is passed, as the apparatus furnishes considerably more air than is required under ordinary operating conditions. The caustic-potash or caustic-soda regenerators are furnished either completely filled and to be thrown away after use, or with a removable cover so that fresh charges may be inserted. The nostrils are closed with plugs of cotton-wool, previously soaked in a suitable grease, and are prevented from falling out by the leather nose-cap, which is fastened to the head with light straps. The nose-cap also being attached to the mouthpiece prevents the latter from dropping out of the mouth, and has no relation to the exclusion of air. The mouthpiece is divided by a thin metal partition, the upper division carrying the air for inhalation, the exhaled air being sucked away through the lower one. The smoke-helmet is provided with a rubber lining to ensure perfect fitting to the face, and is provided with a suitable glass window, but is not furnished with any valves. The apparatus, when fully charged, will allow of about two hours' work.

The trials were successfully completed by four types of apparatus, the exception being the Aerolith, the wearer of which was compelled to withdraw from the trials, owing to lack of air, due to the apparatus not having been properly adjusted.

The results of the trials are recorded in the annexed table.

The thanks of the members of the Institute are due to Mr. C. B. Palmer, for arranging the demonstrations; to Drs. J. W. Mackay and W. L. Ruxton; to Messrs. Henry Armstrong, J. B. Atkinson, P. Phillips Bedson, R. B. Clark, J. J. Simonds, and E. Seymour Wood, who, with the late Mr. M. Walton Brown, assisted by Mr. Percy Strzelecki, acted as observers; to Messrs. W. E. Garforth, Alex. L. Gibbon, W. D. Lloyd, and A. T. Winborn, who generally assisted in the demonstration; and to Mr. Harry Dean for kindly taking photographs of the various apparatus (plates viii., ix. and x.).

[redacted]TS WITH VARIOUS TYPES OF RESCUE-APPARATUS FOR MINES.

[redacted]	Wearer. Pulse. Before trials.	Wearer. Pulse. After trials.	Wearer. Respirations. Before trials.	Wearer. Respirations. After trials.	Time adjusting apparatus to wearer.	Smallest opening through which apparatus can pass.	Time occupied in completing trials.*	Time taken to re-charge apparatus.	Remarks.
	Per minute.	Per minute.	Per minute.	Per minute.	Minutes	Inches.	Minutes	Minutes	
	82	120	24	22	—	—	—	—	Wearer compelled to withdraw, owing to lack of air, due to apparatus not being properly adjusted, as no one experienced in its use was present.
	100	110	24	25	2	17	69	1	—
	94	—	26	22	1	16	76	1·6	—
	84	132	24	22	2	14	57	2·05	While in the carbonic-acid chamber the competitor forgot to open valve of second cylinder, and, showing signs of exhaustion, was withdrawn. He immediately realized his error, and, rectifying it, re-entered the chamber and completed the test. The high pulse-rate might probably be due to excitement caused by his misadventure.
	76	98	20	22	—	17‡ 15§	61	7½	—
	100	77	26	20	—	20	69	—	No re-charge, and therefore did not enter chamber filled with sulphur-dioxide fumes.
	104	110	24	24	—	20	61	—	Mouthpiece came off during the trials, but was at once replaced. No re-charge, and therefore did not enter chamber filled with sulphur-dioxide fumes.

[redacted]several instances competitors were compelled to wait, owing to the man in front not having completed his task.
[redacted]ing jacket. § After loosing jacket.

Mr. T. B. A. Clarke (Hoyland Common) wrote that there was so much interest taken at the present moment in mining rescue-apparatus as a means of dealing promptly and effectively with accident, that everyone who might have to deal with such sudden catastrophes would appreciate the record of the results of the experiments carried out at Felling. Trials were being carried out in the various coal-fields of Great Britain and also in the Colonies; and, in criticizing the tests carried out at Felling, he (Mr. Clarke) was of opinion that they were not exacting or severe enough to test fully the capacity of the apparatus or the endurance of the wearers.

The principle of supplying liquid air from a reservoir did not seem as yet to be practical or reasonably reliable, but the various types of rescue-apparatus which depended on a supply of compressed oxygen would appear to effect the desired result. Of the types described and illustrated in the paper, four were practically the same in principle, though differing, of course, in details.

He (Mr. Clarke) thought that it was not sufficient merely to have a number of rescue-appliances at a station. The equipment should be complete, and should include all spare parts of the apparatus itself, an auxiliary pump for rapidly refilling the working-cylinders, a reviving apparatus, and a special stretcher with oxygen equipment for conveying an injured person to a point of safety.

H.M. Inspectors of Mines would no doubt be anxious and willing to co-operate with the colliery managers in the various coal-fields, with a view to the establishment of rescue-stations at suitable points. In addition to this, every colliery should have an installation of its own on a smaller scale, to enable them to deal promptly with any sudden emergency, though it would subscribe its quota to the central rescue-station and send its own men to be trained in the gallery attached thereto. Having received this training, the men would then perform regular drill at their own colliery in a manner similar and as an adjunct to the ambulance work now being carried on. In order, therefore, to deal effectively with any catastrophe, the following desiderata were, in the writer's opinion, essential:—

(1) Oxygen rescue-apparatus which had successfully passed the severest tests, and could be easily kept in a condition to do so again at a moment's notice.

(2) A corps of men of good physique and intelligence, ready to wear it with the least possible delay, and thoroughly trained in its use and in the use of all supplementary appliances.

(3) Supplementary spare parts, a reviving apparatus, a special stretcher, and an auxiliary pump for rapidly refilling the oxygen-cylinders.

Given a reliable installation, and a means of applying it at once in case of accident, the best results should be obtained with a minimum of risk to the rescue-party. The condition of (1) the heart, (2) the lungs, and (3) the urine of the wearers, when examined medically after a severe test, afforded an index to the merit of each apparatus.

The general opinion was that a rescue-party should consist of five persons, so that to deal with a sudden contingency each colliery should have five sets of apparatus ready to be at once put into use in case of need. The local rescue-party would make a preliminary examination, and by the promptness of their services would probably avert serious disaster. Meanwhile the central rescue-station would be telephoned to, and a party with all necessary reserves of apparatus would proceed immediately to the scene of the accident; they would then be able to receive the report of the pioneer party and replace it for another spell of about 2 hours' work. The writer considers it essential that every rescue-station should be equipped with a telephone, and also with a suitable motor-car to carry men and apparatus.

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from 37 to 38 pounds and not 40¾ pounds as noted in the table. He thought that the tests could not be considered conclusive, as it was impossible to test satisfactorily such apparatus in a natural atmosphere. More recent tests in Lancashire had proved adequately that using an apparatus under natural conditions and using it in an irrespirable atmosphere were two quite different things. Another point to be considered was the difference between highly trained and less efficient men wearing the apparatus. The former might be able to wear it for two hours, whereas the latter might not be able to wear it for half-an-hour. An apparatus which could be worked by a man without previous training had a decided advantage, and long experience had shown that the advantages or disadvantages of the various types of apparatus could not be demonstrated by exhibitions in which the makers' own men competed. The only way to come to a correct conclusion was to try the appliance on oneself, as only then could the faults of any particular apparatus be detected. Since he had been brought into contact with mining men, he had abandoned the idea that it was better in mining rescue-work to have persons who had been specially trained in the use of the apparatus, as he now felt that it was only by having trained pitmen that any good could be done through wearing the apparatus.

Mr. J. B. Atkinson (H.M. Inspector of Mines, Newcastle-upon-Tyne) said that he was not aware that there was a liquid-air plant in Newcastle-upon-Tyne, and perhaps it would be as well that the members should know where it was situated.*

Dr. W. L. Ruxton (Newcastle-upon-Tyne) said that he had examined a number of the Felling competitors before they had commenced their tasks, and his remarks would therefore be offered from a medical point of view on the facts elicited. The paper contained a table in which were given the temperature, pulse and respirations of the men before and after the trials, but the instances were too few in number to furnish a reliable guide as to the effect of substitutes for atmospheric air, or to indicate clearly the advantages and disadvantages of one apparatus over another. It would be noticed that the temperature was generally a little higher after the trials, but the amount of physical

* The liquid-air plant referred to is that installed by the British Oxygen Company, Limited, Boyd Street, Newcastle-upon-Tyne.—Editor.

exertion involved was sufficient to account for the increase, and probably this was the explanation. The pulse-rate was also increased, and this might also be attributed to the same cause. In one instance, the pulse-rate was 100 before and 77 after the experiments; this might be accounted for by the fact that the man was not examined immediately after the tests, and he had probably therefore had sufficient time in which to recover. There was no difficulty with regard to respiration, except in the two cases mentioned in the table, due to the reasons stated.

Referring to the examination of the men, he personally examined six or eight of the candidates, three of whom he had to reject. They all looked physically well, but one had a very high temperature, and had evidently commenced to suffer from the effects of a disease of some sort; another had a heart murmur; whilst the third was too excited and nervous. As regards excitement and nervousness, the man who forgot to turn on the cylinder was probably the most composed of the lot, and yet he lost his self-possession during the trials. He (Dr. Ruxton) felt justified in suggesting one or two essentials in the character of men using rescue-apparatus. In the first place, it was desirable that the men should not be novices, for that accounted largely for the nervous trepidation; anticipation made them excited, and that might be detrimental to their using the means at their disposal. Secondly, physical fitness was absolutely necessary;

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was with reference to such apparatus generally; and it might strike some as being a peculiar question when he asked: What was the purpose for which such rescue-appliances were being so prolifically designed? It seemed to him that there was far too great a tendency at the present time on the part of nearly everybody, with the exception of the few who were the best able to judge, to come to the conclusion that if they could only get "rescue-apparatus" they were going to save a number of lives. It seemed to him that the name given to such appliances was rather delusive. Their sapient law-givers readily rose to the bait, and rescue-apparatus might so attract their notice as to result in laws being passed under false impressions. There might sometimes arise occasions when apparatus of this kind might be useful in mines, but in the whole course of his own experience of mines after explosions he had not come across one single instance where such apparatus would have been of the slightest use. This was rather a sweeping statement, but his experience might not have been so wide as that of others. It struck him that it was not necessary, when an explosion or an underground fire occurred at a colliery, for people to rush away and put helmets on. What was wanted was to enter the mine carefully, and ascertain what the conditions were before doing anything else; and then, before using breathing-apparatus of any kind, they wanted to know where they were going and very definitely for what purpose. Breathing-apparatus was only available for two or three hours, and it was no use putting it on to walk about the pit without knowing what one was going to do. If they knew that beyond a certain foul-air barrier there was a man alive, who could be got out through some extraordinary circumstances, of which he must confess, he had not hitherto had experience, they might put on one of these things for the purpose of getting him out. Even if they did get through the bad air and found somebody alive, they would have to fit him up in a similar fashion or remain with him. He had never yet heard of a single person who had been rescued by means of these appliances, which he first saw in use after the Seaham colliery-explosion in 1880; but both at Courrières and, more recently, at Hamstead the use of such apparatus had resulted in loss of life, and this was the point that he wished to bring out. As to training men in the use of such apparatus, it would be advantageous, provided that

they could keep them trained and the apparatus in order for the long periods of time during which they were not required; for it was during such periods that the men were likely to become heartily sick of the drill and discipline, through not being of actual use. He could imagine, however, such appliances being ten times more useful elsewhere than down the pit, and a disciplined corps of men who could go anywhere would be more useful than a trained band of men for mines only. They might even train colliery men who would not be of much use down a colliery with which they were not familiar. As regards the training generally, to men advanced in years this would no doubt become irksome and be neglected.

Mr. J. B. ATKINSON said that he agreed with a good deal of what Mr. Blackett had said upon this question, and in particular with the statement that many people not acquainted with mining —amateur mining experts, so to speak—thought that there would be a great saving of life by the use of such apparatus, and that if in the case of a colliery-explosion they had a corps of men ready with rescue-apparatus they would bring most of the men out of the mine alive. That, he believed, was an absolute delusion. He had not had direct experience of any colliery-explosion regarding which he could say that the use of such apparatus would have saved any lives; certainly, not the lives of any of those who were in the pit at the time when the accident occurred, although there might perhaps have been some occasions when explorers had

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which would have prevented the smoke from passing into the intake and right round the workings, and possibly there might have been some lives saved. In other cases in Scotland, gases from spontaneous fires had caused loss of life, but he did not know that the use of the apparatus even there would have been the means of saving anyone, though it would have enabled the rescue-party to get to the place sooner than they were able to do. With reference to the case at Hamstead colliery, where the person using the apparatus succumbed, this was probably in consequence of heat apoplexy. He had gone into air heated beyond the normal temperature, and probably had not sufficiently recognized that fact. A man wearing one of these appliances might be all right in smoke, so far as the smoke was concerned, but the effect which the heat would have upon him must be borne in mind, especially when, in using the apparatus, he was already under somewhat abnormal conditions.

Mr. E. Seymour Wood (Murton) said that he was present at these so-called tests, but from his observations he would say that they were simply experiments and unreliable, and were not tests which could be recorded as results of what could be done with the different appliances under actual conditions. He noticed that several of the men during the tests were not even using the apparatus at all, but were resting. The conditions there were quite different from those to be found in a mine containing foul air. If reliable results were to be obtained, tests should be made in a gallery filled with smoke, or in a noxious atmosphere.

Mr. Frank Coulson (Durham) agreed that the apparatus under certain conditions might be very useful. He also agreed with the remarks of Mr. Blackett and Mr. Atkinson; it was useless to rush inbye to get men out, but he thought that they would be more quickly got out if the men wearing the apparatus were to go in front of the fresh air and erect stoppings and clear falls, etc. On this subject it occurred to him that the proper course would be to take fresh air in; and to have a station with appliances for fans or air-compressors driven by motors, which could be taken at once to a colliery where there had been an explosion, when, with a proper construction of air-pipes, the air could be injected inbye very rapidly; the apparatus could be put down the shaft and slung with chains and be put on the ways

as soon as these could be got ready, and in that way they would probably be able to get men out.

Mr. J. J. Simonds (Newcastle-upon-Tyne) said that in connection with the fire-department of the Elswick works of Sir W. G. Armstrong, Whitworth & Company, Limited, they had one of the types of helmet described in the paper. They had never been asked for its use in mines, but it had saved life elsewhere, and had on several occasions proved useful. In one case, in an old tunnel-shaft from a furnace, it was thought that the end had been blocked up, and a man who went in to repair some brickwork collapsed. They were able to get to him with the helmet and to pull him out, and he was resuscitated by means of artificial respiration. Another case where the apparatus was useful was in connection with a refrigerating-apparatus working with ammonia gas. Yet another case was at the Redheugh Gas-works: a valve had become corroded, and it was only by means of a breathing-apparatus that they could get down to close it. Rescue-apparatus would, no doubt, have proved valuable at the fire which occurred at Messrs. Mawson & Swan's premises in Newcastle-upon-Tyne a few years ago, when three firemen died from the effects of descending into a cellar filled with noxious fumes; for with rescue-apparatus they could have gone down quite safely.

With reference to Dr. Ruxton's remarks regarding novices, [redacted]

whether it would be feasible for a man to trail a small wire with him so as to be in such telephonic communication. In the training of rescue-parties it should be a distinct factor that one man should be responsible for the others, and of course they would have to obey him implicitly. Another point which occurred to him was that it would be impossible, supposing that they had fifty or sixty men in a fire-brigade, to give them more than a very cursory idea of what a mine was like; and even miners could not know every mine. It seemed to him that they would have to find someone belonging to the pit in question, who would go down with the rescue-party to show them the way about and to take charge. The firemen would be in charge of the apparatus and would see that it was in the best of condition, but some such person who knew the place would have to be provided at the pit to instruct them as to the work to be done.

Mr. J. B. Atkinson remarked that ordinary firemen would not be of much use in a mine.

Mr. W. C. Blackett said that there was a great deal in what Mr. Simonds had said; the general idea was that miners could go right away into pits with breathing-apparatus on, but this was not so. In every one of the instances which had been quoted where rescue-apparatus had proved of value, the men knew exactly what they were going to do before they went in. In one case a man had to shut a door, in another to close a valve, but a trained pitman was not required for such work. It was more than possible that the nucleus for a general breathing-apparatus station already existed in Mr. Simonds' own hands. There certainly were legitimate uses for such apparatus, but they were more analogous to the uses that were now made by expert divers in water. As to Mr. Coulson's remarks, they, of course, must take air in, but it had never been of great use to send men beyond where they could go with a bird or small animal, and air-pumps would be of little or no use. It was the men who went rushing in beyond the stoppings who were overcome; there was no need for it, and they would not usefully get much further even if they had the apparatus on.

Mr. J. B. Atkinson said that, with the exception of the experiments at Seaham, the only occasion that he remembered of the

use of rescue-apparatus in mines in the North of England was when the Fleuss apparatus was employed at Killingworth in the year 1882*; the downcast shaft had collapsed, and the men had to be brought out by the upcast.

Mr. W. C. BLACKETT: They knew what they had to do.

Mr. T. E. FORSTER (Newcastle-upon-Tyne): And it was the men who wore the apparatus who were rescued.

Mr. J. B. ATKINSON, continuing, said that he did not agree that an ordinary fireman could be sent alone into the mine wearing an apparatus, but he might be taken, as Mr. Blackett indicated, to a definite place for some definite work; he could not be allowed to go any distance, as there were so many dangers—falls of stone, and so on—about which he would know nothing. The idea of a central rescue-station was a good one. In such a station, there could always be half-a-dozen or a dozen miners trained in conjunction with the civilian branch, and they might be very useful. Newcastle-upon-Tyne seemed an ideal place to cover all the collieries in the North of England.

Mr. T. E. FORSTER thought that there was a good deal in what Mr. Blackett said; even if they had trained firemen and pitmen, it would not be much good, unless they had some of the officials of the mine capable of using the apparatus. If half-a-dozen pitmen were turned loose down the pit, they would not

[redacted]

Mr. J. J. SIMONDS said that was the point which he wanted to get at. They would require a body of thoroughly disciplined men who would not lose their heads, led by an official of the colliery, with a definite object, and with apparatus which from experience each fireman knew was in perfect condition. The danger of the amateur element was that the apparatus might lie unused for several years and get out of order.

Prof. HENRY LOUIS (Armstrong College, Newcastle-upon-Tyne) reminded the members of Mr. G. A. Meyer's paper on the Courrières disaster;* in that case a party of men who, as Germans, had the advantage of having been disciplined by military drill, and who carried telephones in with them, had entered the mine, but the only thing that was effected by the use of rescue-appliances was to lose the life of one of the rescue-party.

Mr. H. W. G. HALBAUM (Horden) wrote that he had anticipated, some five or six years ago, the very dangers, etc., to which Messrs. W. C. Blackett and J. B. Atkinson had called attention.† He had then noted the imperfection of such apparatus; and had pointed out the danger, since unhappily demonstrated in practice, of the wearer suffocating himself instead of rescuing others; he had anticipated Mr. J. J. Simonds' idea that disciplined firemen might penetrate a mine, and also Mr. Atkinson's objection that they would do so at their peril. Firemen were, no doubt, among the bravest of men, but, like other men, they were bravest in facing familiar dangers, and the dangers of a mine could only be safely tackled by experienced pitmen. He had likewise anticipated Mr. Blackett's observations anent the danger of turning helmeted men adrift in an exploded mine, without settled and definite plans of action, and the same gentleman's deprecation of the idea of seeking the living among the dead, and of the fallacy of going before the air to put in stoppings, etc. In his concluding remarks he had viewed the case from the standpoint of the practical pitman, and had shown how rescue-operations might be conducted both sanely and safely, and without introducing new perils of the kind referred to. He was glad to have his opinions supported by Mr. Blackett.

* "Rescue-apparatus and the Experiences gained therewith at the Courrières Collieries by the German Rescue-party," by Mr. G. A. Meyer, *Trans. Inst. M. E.*, 1906, vol. xxxi., page 575.

† *Trans. Inst. M. E.*, 1902, vol. xxiv., page 175.

Prof. THOMAS OLIVER, M.D. (Newcastle-upon-Tyne), wrote that it was a disappointment that he had found himself unable to be present at the demonstration with rescue-apparatus at Felling, especially as he had had the opportunity, through the kindness of Mr. W. E. Garforth, of witnessing the experiments carried on at Altofts colliery, near Normanton. So far as concerned the various forms of apparatus, he was only acquainted with the Weg, the Dræger, the Aerolith, and with the Vanginot apparatus, which latter he had seen worn by the fire-brigade men (*sapeurs et pompiers*) in Paris. As there had been recently held another demonstration in Lancashire to settle the question, he would not express an opinion as to the superiority of one form of rescue-apparatus over another.

The main point to be considered was whether it was possible for men wearing safety-apparatus to reach and rescue miners in a pit after an explosion. To accomplish this, several dangers and difficulties had to be overcome. There were not only the dangers and immediate risks to life consequent upon the presence of poisonous gases, but those attendant upon extremely high temperatures and which might be a cause of "heat-stroke." That "heat-stroke" itself might become a cause of death had been placed beyond all doubt. That rescue-apparatus could be worn with safety by men when surrounded by poisonous gases had been fully demonstrated by the experiments which he had seen at Altofts colliery. The men who wore the Weg apparatus were [redacted]

ascertain of what assistance science could be to them in the matter. The demonstrations at Felling and elsewhere had shown what could be done, also what were the possibilities of failure; but it was through a careful study and appreciation of failures that success was ultimately attained. While the use of safety-apparatus might not always allow of a rescue-party reaching miners in a pit and in saving them, it might enable the rescuers to reach particular parts in a pit after an explosion, whereby they might succeed in diverting air-currents or in mending machinery which had gone wrong. It was when entombed miners had been reached by a rescue-party and the men were found to be unconscious that fresh difficulties arose. The men thus found would have to be removed to another part of the pit freer from gas, wearing masks similar to those of the rescuers, and be hurried out of the mine altogether; or some other apparatus would have to be employed to remove the poisonous gases from the blood. Under any circumstances it was advisable that the men who undertook the rescue-work should know the particular mine in question.

The PRESIDENT (Mr. John H. Merivale) said that the thanks of the members were due to Mr. Claude B. Palmer for the trouble and expense which he had incurred in arranging the experiments, to Mr. Lawrence Austin for his valuable record, and to Dr. Ruxton and other gentlemen for the assistance that they had given. Personally, he was pleased to find that after the age of 40 one was not expected to wear the apparatus. He had once tried one on, and certainly felt the nervous excitable feeling alluded to; but he was not sure that the man who was nervous at first was not better than the man who started with more assurance. He sympathized with the suggestion that they did not want any more legislation in connection with mines in the North of England. Although at first sight there might not appear to be a great deal to be got out of rescue-appliances, it was their duty to foster anything that advanced knowledge. They were not merely an Institute of mining engineers: they had a much broader foundation than that; and though at present it did not seem likely that such apparatus could be of much use in mining, they had heard that in other branches of industry the apparatus had been of service in the past, and probably would be so in the future. He thought,

therefore, that it would be wise for them to support the proposal for having some central station with men trained in the use of the various types of so-called rescue-apparatus. Perhaps Mr. Simonds, with his practical knowledge of the matter, would be prepared to write a paper dealing with the organization of such a central station. In conclusion, he moved that the thanks of the members be accorded to Mr. C. B. Palmer for arranging the experiments, and to Mr. Lawrence Austin for his record of them.

The votes of thanks were carried unanimously.

FLINTY CHERT, HORNSTONE, ETC.

By THOMAS HARKER.

Character.—Flint may sometimes be observed passing into a substance of a more opaque and earthy nature, but equally hard. This substance, which has received the name of chert, or hornstone, may be regarded as an earthy variety of flint. Chert is always of a hardness sufficient to scratch steel or glass, and, when not porous, has a specific gravity ranging from 2·55 to 2·65. It is insoluble in all acids, with the exception of hydrofluoric acid, and is infusible before the blow-pipe.

Geological Distribution, etc.—All the chert which is being worked in England and Wales occurs in the Carboniferous Limestone Series or in the Millstone Grit. It also frequently occurs in large masses in and below the Chalk. In the Yoredale strata it is found, as a general rule, between the limestone and the plate (shale) and sandstone-beds, next above it. In the southern counties of England, the same mass of chert presents the appearance of perfect chalcedony in one part and of flint in the other, showing the near connexion of these minerals, which are in reality only different varieties of the same substance. In Derbyshire, where the chert occurs in the Mountain Limestone, the flint differs greatly from the flinty chert of the northern and southern counties. It appears to have undergone some chemical change during its formation, and is fusible.

Chert-mining is, at the present time, carried on at Bakewell in Derbyshire, in the Halkyn mountains in Flintshire, and in Swaledale in Yorkshire. There are five distinct beds of chert in the North Riding of Yorkshire, all somewhat different in nature, as follows:—(1) Flinty chert, 16 feet thick, lying 87 feet below the Millstone Grit; (2) Crow chert, 6 feet thick, lying 6 feet below the Flinty chert, the intervening strata being plate; (3) Second Crow Chert, 15 feet thick, lying 6 feet below the Crow chert, the intervening strata again being plate; (4) Main

chert, 18 feet thick, lying 196 feet below the Second Crow chert and only 18 inches above the Main or Twelve-fathom limestone, the strata immediately above it being plate, 4 feet thick; and (5) Undersett chert, 24 feet thick, generally of a hard nature and very much darker in colour than the other beds, lying 60 feet below the Main or Twelve-fathom limestone and 6 feet above the Undersett limestone, the strata immediately above and below being plate, 22 feet and 6 feet thick respectively.

On the western side of the valley of Arkingarthdale most of the cherts have proved very productive in lead-ore, whilst on the eastern side of the dale they have proved practically unproductive. It is remarkable that the Undersett chert, which is being worked in the neighbourhood of Reeth, on the eastern side of Swaledale, produces some of the finest flinty chert, of the same nature as that worked on the western side of the dale, but the latter bed lies no less than 100 feet higher up in the series. The writer is not aware of any other locality where the Undersett chert is of such a flinty nature as at Reeth, chemical change no doubt being the cause.

Analyses.—The following analyses of chert sold to the Potteries are taken from Mr. Hubert L. Terry's paper on "Chert-mining in England and Wales":—*

	Derbyshire.		Swaledale.	Flintshire.
	Per cent. (1)	Per cent. (2)	Per cent.	Per cent.
Water	0·54	0·60	1·61	1·32

[redacted]

Mr. BENNETT H. BROUGH (London) thought that for purposes of comparison it might be useful to add to the interesting series of analyses of chert sold to the Potteries the best known Continental analysis, that by Ricciardi of a sample from Sicily, which was found to contain 96·31 per cent. of silica, 0·30 per cent. of alumina, 0·25 per cent. of ferrous oxide, 0·47 per cent. of lime, and 2·81 per cent. of water. The inception of the mining of flint was much earlier than the initiation of the use of flint in the manufacture of pottery in 1777. In the Stone Age flint was mined for tools and weapons in East Anglia, and mining still continued at Brandon, in Suffolk, for the purpose of supplying gun-flints for savage tribes. The method of mining the flint and of preparing the gun-flints was described in 1879, by Mr. Sydney B. J. Skertchly.*

Mr. J. B. ATKINSON (H.M. Inspector of Mines, Newcastle-upon-Tyne) said that Mr. Harker's paper was an interesting geological contribution, and he would like to know the scientific definition of chert. Chert occurred in the Carboniferous Limestone of Swaledale; what were the corresponding beds in Northumberland and Durham? It struck him that the gannister beds might correspond to the chert-beds, and that the stratum called "tuft" in the lead-mining districts was of the same nature, though apparently not so solidified or bound together as the chert. According to the analyses given in the paper, the two samples of chert from Derbyshire contained a considerable proportion of carbonate of lime; whilst that from Swaledale contained only 1·86 per cent., and that from Flintshire 0·43 per cent. Should lime be considered as one of its constituents?

Prof. HENRY LOUIS (Armstrong College, Newcastle-upon-Tyne) said that he had seen the Swaledale chert-beds worked in the neighbourhood of Richmond, where they occurred in the upper beds of the Mountain Limestone. He did not think that carbonate of lime was an essential constituent. Chert was probably a hydrated silica, but he did not know that any precise definition had ever been laid down.† The oxide of iron was a

* *Memoirs of the Geological Survey of England and Wales: On the Manufacture of Gun Flints, the Method of Excavating for Flint, the Age of Palæolithic Man, and the Connexion between Neolithic Art and the Gun-flint Trade*, by Mr. Sydney B. J. Skertchly, 1879.

† The definition given by Mr. J. D. Dana (*A System of Mineralogy*, fifth edition, 1872, page 195) is the conveniently vague one of "any impure flinty rock."—H.L.

serious disadvantage in chert used for pottery purposes; chert should be as free as possible from this, as it had a very deleterious effect on its colour properties. He did not quite agree with the author's view that chert occurred in large masses in and below the Chalk. He believed that what they got in the Chalk were flints, which were distinctly different in their mode of occurrence, and were, moreover, mostly, if not always, of organic origin; but he confessed that his knowledge of the subject was limited. He did not associate chert with gannister.

Mr. J. B. Atkinson said that a bed of gannister was being worked, near Fourstones, which was closely associated with the Great Limestone, very much as the chert-beds were in Swaledale.

Prof. H. Louis said that he thought that their mode of occurrence was essentially different.

Mr. W. M. Egglestone (Stanhope) wrote that there were no chert-beds in the Mountain Limestone strata forming the lead-measures of Weardale. Whilst the main chert-bed of Swaledale, in Yorkshire, overlay the Main Limestone, the beds overlying the Main or Great Limestone of Weardale were, in ascending order, shale or plate, low-coal sill, sandstone, coal, shale, high-coal sill, coal, shale, Little Limestone, etc. Nattriss-gill hazle, a close-grained sandstone, underneath the Four-fathom Limestone, and some 44 feet below the Great Limestone, was, with other sandstones, the gannister of Weardale. At Wolsingham, down the [redacted]

Referring to the Bakewell mineral, in Derbyshire, "it is more truly intermediate between limestone and chert, being a limestone that has been partly replaced by chert."*

Prof. Cole referred to chert as retaining some of the features of the original limestone, and instanced the chert of the Assynt Limestone at Stronechrubie, Sutherland, as preserving in the most exquisite manner the oolitic structure that doubtless once prevailed throughout considerable masses.†

The flints used by Palæolithic and Neolithic man for their implements of war, etc., were evidently from the Chalks, and it might be asked whether the flints which Mr. Astbury, a Staffordshire potter, who was credited as being the first to introduce flints to the Potteries in 1720,‡ were not also Chalk-flints. These flints appeared to have been formed by the aggregation of siliceous matter around various organisms which served as nuclei, whilst the mode of occurrence of the Carboniferous Limestone cherts, referred to in Mr. Harker's paper, appeared to have been, as Prof. Henry Louis had said, distinctly different.

On the motion of the PRESIDENT, a cordial vote of thanks was passed to the writer of the paper.

The following paper by Mr. WILLIAM MORLEY EGGLESTONE on "The Occurrence and Commercial Uses of Fluorspar" was taken as read:—

* *Memoirs of the Geological Survey of England and Wales: The Geology of the Carboniferous Limestone, Yoredale Rocks and Millstone Grit of North Derbyshire*, by Messrs. A. H. Green, C. Le Neve Foster, and J. R. Dakyns, second edition, with additions by Messrs. A. H. Green and Aubrey Strahan, 1887, page 166.

† *Aids in Practical Geology*, by Prof. Grenville A. J. Cole, 1891, page 187.

‡ *Handbook to the Collection of British Pottery and Porcelain in the Museum of Practical Geology*, 1893, page 29; and *Chemistry of Porcelain, Glass and Pottery*, by Dr. Shaw, 1837, page 248.

THE OCCURRENCE AND COMMERCIAL USES OF FLUORSPAR.

By WILLIAM MORLEY EGGLESTONE.

I.—Occurrence, Etc.

Introduction.—Fluorspar in England is practically confined to the counties of Derbyshire and Durham, and statistics for recent years show a wonderful boom in this mineral as a commercial product. The "Blue John" of Derbyshire was discovered at an early date, whilst in Weardale, County Durham, fluorspar, as a bye-product, was not considered of any commercial value until recent years; although as a waste-product it has been known in the dale for at least seven-and-a-half centuries.

Government returns show that the output of fluorspar in England during the year 1873 was *nil*, and that during the ensuing twenty-seven years 1,000 tons per annum was only twice exceeded. The figures for the succeeding years are as follows, those relating to the United States of America being also given:—

Year.	Weardale.	United Kingdom. Quantity.	United Kingdom. Value.	United States.
[redacted]				

48·72 per cent.* It has a perfect octahedral cleavage, its lustre is vitreous, and it crystallises in the cubic or tesseral system. It has a specific gravity of 3·1; its hardness (Mohs' scale) being 4. It occurs in massive or amorphous and crystalline forms, twins, druses, and single crystals, and is frequently invested by other minerals such as quartz, siderite, blende, etc. With the blowpipe, the flame-coloration is fairly good; it decrepitates to a great extent, but finally fuses at 2·5 to 3, with ebullition. In a closed tube fluorine-reactions are well given.† Diathermanous bodies are those which transmit radiant heat readily, and in respect to the diathermancy of fluorspar Prof. H. Adams quotes the following percentage scale by Mr. J. Spencer:—Dry air, 100; rock-salt, 92; fluorspar, 72; Iceland spar, 39; plate-glass, 39; distilled water, 10; alum, 9; and ice, 6.‡

Historical.—The history of ornamental fluorspar dates from pre-historic times to the present day. It is stated by Mr. S. F. Emmons,§ who quotes from Mr. G. F. Kunz,‖ "that the mineral was known to the Indians, is proved by the discovery, in some of the pre-historic mounds of the region, of fluorspar, shaped into ornaments." Then Mr. W. Royse, in his account of the "Blue John" spar-mines at Castleton, Derbyshire, speaks of the hill, in which the mines and caverns of this mineral are found, as being called Tray or Tre cliff, and states that in this district the Romans worked the Odin lead-mine, which was afterwards worked by the Saxons, who gave it the name of Woden, from the Saxon god of that name; and also that it was the Romans who first discovered the "Blue John." We are further told that, in excavating at the ruins of Pompeii, two large "Blue John" vases of excellent workmanship were found, so that, for ornamental purposes, this spar came into use not only 2,000 years ago, but in pre-historic times. The price in 1891 was quoted at between £12 to £800 per ton, according to quality. Fig. 1 is an illustration of vases made from Derbyshire "Blue John."

* *Textbook of Descriptive Mineralogy*, by Mr. Hilary Bauerman, 1884, page 376.

† *Aids in Practical Geology*, by Prof. Grenville A. J. Cole, 1891, page 67.

‡ *Cassell's Engineers' Handbook*, by Prof. Henry Adams, page 255.

§ "Fluorspar-deposits of Southern Illinois," by Mr. S. F. Emmons, *Transactions of the American Institute of Mining Engineers*, 1892, vol. xxi., page 31.

‖ "American Gems and Precious Stones," by Mr. G. F. Kunz, *United States Geological Survey: Mineral Resources of the United States*, 1882, page 497.

Mr. J. H. Cardin also states that "Tradition says that it was in this chamber [the crystal chamber] that the inhabitants took refuge when in fear of the Young Pretender and his adherents, in the year 1745, and either to pass away the time or to frighten any intruders, they carved out from the solid spar a figure in the shape of a lion."*

Colour, etc.—The term "fluorescence" was first applied to a physical property observed in this mineral, namely, that when exposed to light fluorspar becomes fluorescent—a peculiar colour appearance akin to phosphorescence. Fluorspar, when cracked along the cleavage-planes or when possessing edge-fractures, has,

[redacted]

This mineral possesses quite a suite of colours. One may have a colourless crystal of fluorspar, then one with a faint purple shade or with all the shades or tints from pinkish to deep violet or blue. Pink or rose-coloured fluorspar is rare, but all shades of purple to deep violet are common in the mineral. Amethystine colouring is seen in specimens from the Sedling lead-mine, Weardale. A hand-specimen of transparent or semi-transparent crystals of this amethystine tint looks rich and beautiful. At White's Level lead-mine, Weardale, nearly all the fluorspar got, in former days, was of a beautiful transparent green and emerald-green. Specimens of pale, muddy, pea-green crystals, in druses or groups, frequently show in the centres of the cubes a curded white appearance, which might be called clouded, or having a cauliflower-like appearance. These crystals are opaque. Pink crystals have been found at Boltsburn mine, Weardale. A beautiful pink variety is found in Switzerland.

The writer has frequently seen green crystals from the Weardale mines, with bevelled edges, that is, showing a face running along all the edges of the cube. White's Level lead-mine, Weardale, sometimes yielded these bevel-edged green cubes, some of which contained liquid-cavities and vapour-bubbles. Mr. H. Bauerman states that "the lead-mines near Liskeard [Cornwall] produce pale-green cubes of considerable size, having the solid angles modified by planes of hexakisocta-hedra."* Flesh-red hexakisoctahedrons occur at Münsterthal in Baden.† Mr. F. W. Rudler, under Cornwall and Devon, mentions the four-faced cube, known technically as the tetrakis-hexahedron, which has the edges bevelled, as being known as the *fluoroid*.‡ Mr. Rudler also states that the faces of a cube of fluorspar, instead of being quite plain, may show markings which represent a very low square pyramid, these facets being known as *vicinal* faces.§ The writer has in his possession an amber-coloured cube, found near the Red vein at Stanhope, with square lines or markings running to a central point on one face of the cube.

* *Textbook of Descriptive Mineralogy*, by Mr. Hilary Bauerman, 1884, page 377.

† *A System of Mineralogy*, by Prof. James Dwight Dana, fifth edition, 1872, page 125.

‡ *A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection, in the Museum of Practical Geology*, by Mr. F. W. Rudler, 1905, page 86.

§ *Ibid.*

Mr. H. Bauerman refers to a coloured variety, the crystals of which are dark green in the centre and bright blue along the edges, as being characteristic of Weardale.* Wine-yellow or amber-coloured fluorspar sometimes occurs in Weardale, Killhope Head mine having produced amber, bright-blue, and dull pea-green coloured fluorspar. Boltsburn mine, Weardale, a rich present-day lead-mine, belonging to the Weardale Lead-mining Company, Limited, presents, in the "flats" or horizontal deposits of galena, perhaps the most magnificent display of galena and of purple crystalline fluorspar ever seen in the North of England lead-mining field. Cubes of purple spar up to 10 inches on the side are scattered about in various directions in the caverns or lough-holes and workings associated with these galena flats.†

The writer possesses cubes with 3-inch sides of a deep and rich violet-blue or plum-blue colour, which are practically opaque. In some of the specimens the colour is ribbon-banded, as in chalcedony. In others, it would appear as though there were an inner cube of purple encased in a colourless deposit one-sixteenth of an inch deep, yet there is but one solid cube, the appearance being due to colour in the first deposit and a later enveloping deposit of colourless fluorspar.

Cause of Colour.—Mr. H. Bauerman states that "the colour of fluor is probably due to some hydrocarbon compound, as most of the dark-coloured varieties are bleached, or turn to a pale yellow, when heated up to the phosphorescing point. Bubbles [redacted]

his experiment, he tested fluorite of different colours, including violet, dichroic, yellow, green, blue and white varieties, and found that all specimens that possessed odour contained hydrocarbons, whilst colourless fluorite from Cumberland had no odour and contained no hydrocarbons. Considering these experiments, and the fact that the decolourisation of the mineral was attained by moderate heating, Mr. W. S. Tangier Smith agrees with Mr. Wyrouboff's conclusions.*

Referring to Mr. Wyrouboff on the colour of fluorspar, Mr. F. W. Rudler observes—

"More recently the studies of K. v. Kraatz-Koschlau and Lothar Wöhler have supported Wyrouboff's views.† They found in a violet fluorspar from Weardale 0·01 per cent. of carbon and 0·008 of hydrogen, in blue and green fluor from Cumberland 0·009 of carbon and 0·002 of hydrogen, and in yellow fluor from Durham [Weardale] 0·007 of carbon and 0·0025 of hydrogen; whilst the colourless fluor was free from either of these elements." ‡

Hydrocarbons are compounds of carbon and hydrogen, being gaseous when hydrogen predominates, liquid with less hydrogen, and solid when carbon predominates. Hydrocarbon compounds appear to be plentiful in the Derbyshire lead-mines, at Windy Knoll quarry, near Castleton, and at other places in the neighbourhood.

Perhaps Weardale and Allendale stand at the head in the North of England for beautiful fluorspar, the brilliant colour and symmetry of form of its fluorspar being the trade-mark and pride of Weardale. This was noticed by the late Mr. Thomas Sopwith, who stated that—

"The beautiful spars which adorn the mantel-pieces of many houses in the northern towns are often designated by the general name of Alston Moor spars. But only a very small proportion of them are the product of veins in this manor, by far the most beautiful and abundant of these specimens being found in the mines of Weardale and Allendale. Fluorspar of different colours, quartz, and the ore of zinc, blende and calamine, or 'Black Jack,' as it is locally termed, are the prevailing spars of Alston Moor." §

* "The Lead, Zinc, and Fluorspar-deposits of Western Kentucky," by Messrs. E. O. Ulrich and W. S. Tangier Smith, *United States Geological Survey: Professional Papers*, No. 36, 1905, page 125.

† "Die natürlichen Färbungen der Mineralien," by Messrs. K. v. Kraatz-Koschlau and Lothar Wöhler, *Min. Mitt.*, 1899, vol. xviii., pages 304 and 447.

‡ *A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection, in the Museum of Practical Geology*, by Mr. F. W. Rudler, 1905, page 174.

§ *An Account of the Mining Districts of Alston Moor, Weardale, and Teesdale*, by Mr. T. Sopwith, 1833, page 110.

Dealing with fluorite, as represented in the Museum of Practical Geology, Mr. F. W. Rudler points out that some of the finest known crystals of fluorite have been obtained from the northern lead-mining districts, especially from the mines of Weardale, county Durham. The large series of representative specimens exhibited in the museum include, we are told, many crystals which rival the fluors from Derbyshire, Cornwall, and Devon. These northern fluors are generally crystallised in simple cubes which, in most cases, are boldly and symmetrically developed. A cube of Weardale purple fluorspar is mentioned as being extended along one axis, so that the face represents a long rectangle parallelopipedon.* For its fluorspar, then, Weardale can hold its own.

Drop Diamond (fig. 2.) — Single cubes of Weardale fluorspar are sometimes the special product of some mine or part of a mine. Half-a-century ago, White's Level lead-mine had a clay-drift [redacted]

(fig. 2), in which is a liquid cavity with an air-bubble, having, like a spirit-level, a run of half-an-inch. Such bubbles vary in size from those invisible to the naked eye to the size of a buck-shot. In the study of liquid cavities with air-bubbles found in quartz and other rocks, experts state that, from this character, an estimate may be made as to the pressure in thousands of feet under which such rocks, granite and others, have consolidated, and as to the corresponding temperature.

Fluorspar Prisms.—A piece of fluorspar broken off a cube along the cleavage planes was found, by the writer, to be of prism-shape, and on being placed over a small object, two objects appeared; on raising the prism, the distance between the objects widened, according to the distance to which the prism was raised. The writer also has had a piece of light purple fluorspar cut into the shape of a prism, and polished by an expert, its refraction being perfect.

FIG. 3.—INVESTED FLUORSPAR.

Minerals Investing Minerals (fig. 3).—Fluorspar plays an important part in this interesting phenomenon of one mineral investing another. If the investing mineral is siderite, the specimen is said to be "rusted," and when invested with small clear crystals of quartz (rock-crystal), it is locally said to be "frosted." More than fifty years ago, Sir Warington W. Smyth, when writing on the iron-ores of Weardale, called attention to the many cases of incrustations on the previously-formed crystals of fluorspar and galena, and, further, to the striking manner in which it was often found to coat only particular crystallographic faces.*

* "Iron-ores of the Northern and North-midland Counties of England (Cumberland, Durham, Northumberland, Lancashire, Yorkshire, and Derbyshire)," by Mr. Warington W. Smyth, *Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology: The Iron-ores of Great Britain*, 1856, page 19.

In the *Handbook to the Museum of Practical Geology*, it is pointed out that in many of the specimens crystals of a later-formed mineral have been deposited on particular faces only of the pre-existing mineral, the laws determining this selective action being in many cases far from obvious.

The writer has noticed that specimens of fluor, quartz, and other spars from the Weardale lead-mines are very frequently invested on faces of the pre-existing crystals in one direction only, whilst the faces in the opposite direction represent the natural faces of the older mineral which is invested. Fluorspar, quartz, galena, calcite, iron-pyrites, siderite, and zinc-blende are the minerals found investing each other. Fluorspar is frequently found invested with quartz and siderite, and groups of quartz-crystals are often incrusted with siderite. All this investment seems to follow one law: that of incrusting one side only of the crystals receiving the investing mineral; whilst the pre-existing minerals show comparatively large crystals, the secondary or investing mineral consists of small crystals. A description of a few specimens in the writer's possession may be of interest. A group of quartz-crystals is invested, on one side only, with a snow-like dust, which, on examination, proves to be a mass of clear white crystals of fluorspar. It may be mentioned that the drusy quartz-crystals which are thus invested had previously invested fluorspar-crystals, so that we have fluorspar invested with quartz, which mineral again is invested [redacted]

cut and polished diamonds. The question may be asked: why this one-sided investment?

Fluorspar Enveloped in Chalcedony.—The writer has a section of a hand-specimen of quartz, which he has had polished, and this shows in the centre two greenish fluorspar cubes, about ⅝ inch across. These cubes are invested with banded white-and-brown wavy chalcedony, which follow the squares of the fluorspar. Finally the banded chalcedony is covered with quartz, about ½ inch thick.

Crystals within Crystals.—Specimens of this class are most interesting, exhibiting as they do the crystal of one mineral embedded in the solid crystal of another mineral. Nicolaus Steno* sets forth (1) that rock-crystal has once been liquid, as is shown by the way in which it encloses other bodies; and (2) rock-crystal may increase in size, as is proved by the fact that sometimes stages in the growth are indicated by the positions of the enclosures.†

Specimens in the writer's possession fully support the above statement, fluorspar being the enclosing and rock-crystal the enclosed mineral, and *vice versa.* In this interesting phase in the life-history of fluorspar may be observed some most wonderful phenomena. In one specimen (a cube of fluorspar an inch or so on the side), the purple stage had evidently been suspended and a number of small quartz-crystals had formed or settled down on the upper face of the cube. Then the fluorspar-crystal had commenced to grow again, and, without being influenced in the slightest degree by the quartz-crystals, put on a band of pure colourless fluorspar, in which the rock-crystals were embedded. Another specimen, consisting of a drusy group of milky-white pyramids of quartz, has embedded in the pyramids small cubes of galena and also small cubes of pale-pink fluorspar—these two minerals, in some cases, being very near each other. Another group of quartz-pyramids have embedded in them small blackish specks of specular iron. In a third specimen (a cube of clear purple fluorspar) are embedded several perfect specimens of rock-crystals having the double pyramid.

* *De Solido intra Solidum naturaliter contento,* by Nicolaus Steno, Florence, 1669; English translation, 1671.

† *British Museum Mineral Department: Introduction to the Study of Minerals, with a Guide to the Mineral Gallery,* by Mr. L. Fletcher, 1897, page 24.

Weardale Fluorspar.—The Burtreeford fault has, apparently, had considerable influence in regulating the mineral-deposits in the veins of Weardale and the surrounding country. This dislocation crosses Weardale from the north at the village of Burtreeford, near Cowshill, and continuing in a southerly direction it runs through Burnhope into Teesdale. It has a downthrow to the east of 80 fathoms, which appears to have placed the rocks at an horizon favourable to the deposition of fluorspar. Westgarth Forster pointed out that the metalliferous veins east of this great fault were generally of a softer nature than those on the west side, and contained generally, as a matrix, calcareous spar and fluorspar, as at Allenheads and in the extensive mines in Weardale and Derwent, all of which are on the east side of the fault. The lead-mines at Coal Cleugh, Alston Moor, and Killhope, and also the upper Teesdale mines, are all on the west side of the fault, the metalliferous veins being generally of a harder nature, and the accompanying minerals contain a good deal of zinc-blende and rider and also cauk or barytes.* Mining operations have amply proved these statements to be correct. The same writer also pointed out that the once celebrated Cross Fell lead-mine and the veins east of Cross Fell generally contained "amorphous" fluorspar and galena, whilst the veins on the west side of the mountain were filled with sulphate of barytes and galena.†

A writer on the Yorkshire mines states that fluorspar is [redacted]

In the lead-mining districts, it occurs perhaps in nearly all the veins of one part, while in the veins of an adjoining area, traversing precisely the same rocks, and, to all appearance, produced under precisely similar conditions, it is frequently conspicuous by its absence."*

This is supported by the previously-mentioned fact that Weardale and Allenheads veins, on the east side of the Burtreeford fault, are the most productive of fluorspar in the North of England lead-mining districts. Nearly all the metalliferous veins in the Lake District are quartz-veins.

Origin of Fluorspar in Veins.—Fluorine was unknown in the free state until some twenty years ago, when it was "obtained as a colourless gas which decomposes water, liberating oxygen and combining with hydrogen to form hydrofluoric acid."† Prof. Lewes also states that—

"The four elements fluorine, chlorine, bromine, and iodine, exhibit a gradual difference in properties and in their power of combining with other elements, fluorine having the greatest affinity for metals and iodine the least; whilst the solubility of the compound formed in combining with oxygen is in reverse order, iodine forming the strongest compound: fluorine is the only element which does not combine with oxygen." ‡

Considering that fluorine has a great affinity for metals, and that it does not combine with oxygen, and, further, that silicon is not acted upon by any acid except hydrofluoric, with which it forms silicon fluoride, it would not be surprising to find that this element played some active part in the deep-seated rocks in respect to the change of mineral matter. Mr. J. H. Collins calculated that the tourmaline-bearing rocks of the West of England contained something like 2,480,000 tons of fluorine for each yard in depth.§

It has been stated, with reference to the origin of clay, that "the kaolinisation of felspar may be effected by ordinary weathering, yet in most cases the alteration has probably been brought about by subterranean rather than by superficial agencies. It is notable that in Cornwall, where the decomposition of

* "Contributions towards a List of the Minerals occurring in Cumberland and Westmoreland," by Mr. J. G. Goodchild, *Transactions of the Cumberland and Westmoreland Association of Literature and Science*, 1882, part vii., page 114.

† *Service Chemistry*, by Professor Vivian B. Lewes, second edition, 1895, page 353.

‡ *Ibid.*

§ "On the Origin and Development of Ore-deposits in the West of England," by Mr. J. H. Collins, *Journal of the Royal Institution of Cornwall*, 1893, vol. xi., page 371.

the granite has proceeded to great depths, the kaolin is usually accompanied by minerals containing compounds of fluorine and boron; and a similar association has been observed in other china-clay districts. The characteristic associates of the altered felspars in the clay-yielding granites are such minerals as tourmaline, lepidolite, topaz, apatite, and fluorspar."*

Other fluorine minerals are fluellite, a hydrated fluoride of aluminium; cryolite, a double fluoride of aluminium and sodium, from Greenland; tourmaline, a boro-silicate, containing about 2 per cent. of fluorine; and apatite, a phosphate of calcium, associated with either a chloride or a fluoride of the same metal, known as chlor-apatite and fluor-apatite respectively.

As far back as 1824, Mr. Leopold von Buch suggested that certain kaolins had probably resulted from the action of compounds containing fluorine, rising from deep-seated subterranean sources, and attacking felspathic rocks.† And further, these views were modified and extended by Mr. A. Daubrée, who supported them by ingenious experimental evidence.‡ It is worth noting, too, that Mr. J. H. Collins has effected the kaolinisation of felspar by means of hydrofluoric acid.§

Metasomatism.—Several American writers, including Messrs. H. Foster Bain, S. F. Emmons, E. O. Hovey, W. S. Tangier Smith, and others, have studied the formation of fluorspar-veins. The general conclusion appears to be that the original fissures have been filled with the mineral, whilst a good deal of replace-

[redacted]

This writer is also of opinion that the known facts "point to the derivation of the fluorspar from the mass of the surrounding limestone."*

Another writer, of later date, Mr. W. S. Tangier Smith, referring to metasomatic replacement, says that "the question arises what proportion of the massive fluorite of the fissure veins, if any, has been formed by the replacement of the limestone composing the walls of the original fissure?"† He points out that "there is little evidence bearing on this point, and that of a negative character. From the facts determined, however, the writer [Mr. W. S. Tangier Smith] is led to the conclusion that the veins have been largely formed by fissure-filling, although in some cases it is probable that there has been more or less replacement of the country rock by fluorite."‡ This writer further mentions that at the Columbia mine "a part of the limestone had been replaced mainly by sphalerite, the rest mainly by fine-grained fluorite, associated with very little sphalerite. The fluorite in thin section still shows outlines of some of the microscopic fossils originally contained in the limestone."§

Referring to the fluorite-deposits in Southern Illinois, Mr. H. Foster Bain says that—

"In general the great width of the vein is probably due to the facility with which the less soluble calcium fluorite is formed in the place of calcium carbonate whenever fluorine is available. This has resulted in extensive replacement of the limestone wall through metasomatic processes . . . . . This process is not believed, however, to have operated to the exclusion of normal vein-filling in open cavities, since, for example, in the McClellan mine . . . . there is a considerable body of clear fluorspar where both walls are sandstone and where, accordingly, there is little opportunity for simple replacement. . . . . The co-operation of the two processes of open fissure-filling and metasomatism is, as Mr. Lindgren has shown, normal and quite in accord with what should be expected."||

Mr. Bain further points out that—

"There are two broadly contrasted methods by which the present ore-bodies may have been concentrated. The first is by the action of the normal

* "Fluorspar-deposits of Southern Illinois," by Mr. S. F. Emmons, *Transactions of the American Institute of Mining Engineers*, 1892, vol. xxi., page 52.

† "The Lead, Zinc, and Fluorspar-deposits of Western Kentucky," by Messrs. E. O. Ulrich and W. S. Tangier Smith, *United States Geological Survey: Professional Papers*, No. 36, 1905, page 142.

‡ *Ibid.* § *Ibid.*, page 139.

|| "The Fluorspar-deposits of Southern Illinois," by Mr. H. Foster Bain, *United States Geological Survey: Bulletins*, No. 255, 1905, page 41.

meteoric waters . . . . which may . . . . have gathered the disseminated material from the country rocks into the veins. The second is by the action of heated waters, either originally meteoric or derived from the intruded igneous rock, or in part from each source. It is believed that the evidence points to heated waters having been the agency by which the ores were segregated and that they obtained an essential portion of their load from a large mass of lower-lying intruded rock, of which the dikes are the offshoots."*

After considering "that the ore-bodies show no sign of secondary enrichment, and apparently the surface-waters now in the region can only operate to destroy rather than re-form the ore-bodies,"† Mr. Bain refers to fluorite as being relatively insoluble in cold water as compared with limestone, and states that crystals of fluorspar in druses are relatively rare; he concludes that "It is difficult to believe, therefore, that such waters have gathered minutely disseminated quantities of fluorite from the surrounding limestone and formed the veins as they now occur."‡

Mr. Bain also points out that—

> "Fluorine has commonly been observed in connection with volcanic outbursts, and fluorite is one of the most common minerals connected with volcanic rocks. At Cripple Creek, Colorado, and many other western camps it is abundant in intrusive and extrusive rocks of Tertiary age. So far, then, the igneous rocks form a very probable source of the fluorine, but the evidence that the material did actually come from them is weak."§

In the *Memoirs of the Geological Survey of England and Wales*, reference is made to one of the so-called veins, which [redacted]

Such is one of the fluor-flats of North Derbyshire. The metalliferous veins in the Weardale, Allendale, and Alston districts are nearly vertical, but have, as a rule, a hade to one side; there are also flat or horizontal deposits, the matrix, especially in Weardale and Allendale, being fluorspar. There is one exception in Weardale, namely, the vein running eastward from the Billing Hills, this being a quartz-vein. Fluorspar-veins below the weathering-belt, and sealed up in the solid rock, would be little affected from above, whilst veins above the weathering-belt would be subject to weathering and decomposition, and secondary deposits would take place, but relatively to a small degree. Cracks and fissures are the natural channels for vein-filling, and is it not as easy to say that country rock might be enriched from the veins as that veins were enriched from the country rock? Clearly, the metasomatic action which converted the limestone into ironstone is evidence of rock enrichment from the metalliferous vein. Cavities in limestone in connection with such veins above the weathering-belt get filled with minerals in a crystalline form whilst cavities in limestone not near mineral veins are more likely to be filled with calcite or clay. The writer has seen large pieces of cleavage-calcite taken from cavities in the Great Limestone at Stanhope where there are no metalliferous veins in close proximity.

Dr. Edmund Otis Hovey points out that "a peculiarity of the Kentucky-Illinois district is the association of basic igneous dikes with the veins of fluorspar."* Mr. Bain refers to the significant fact that fluorite is entirely absent in Northern Illinois but occurs in quantity in the Southern Illinois district.

No doubt metasomatic action plays no inconsiderable part in the formation or, more correctly, the alteration of rocks and minerals. Mr. J. D. Kendall, referring to the original iron-ores of Alston Moor and Weardale as being siderite, from which limonite was produced by alteration, states that it (siderite) was formed by replacement of the limestone by solutions of iron, connected with volcanic agency.†

Referring to the hæmatite-deposits of Cumberland, Prof. Henry Louis is of opinion that Mr. Kendall's explanation of the

* "Fluorspar," by Dr. Edmund Otis Hovey, *United States Geological Survey: Mineral Resources of the United States*, 1905, page 1100.

† *The Iron-ores of Great Britain and Ireland*, by Mr. J. D. Kendall, 1893, page 327.

origin of these ores is probably the correct one, that is, he considers them to have been formed by metasomatic replacement of the limestone by solutions of iron.*

Early Mention of Fluorspar in Weardale.—As early as the year 1666, one at least of the Weardale mines was called "Spar Grove," owing no doubt to the abundance of fluorspar. During all the years of lead-mining in the dale, going back at least to the time of King Stephen, fluorspar, in thousands of tons, has been deposited generally in rivers and streams, and being soft would be ground into fine sand. The crystalline forms with all their beautiful symmetry and colour have always been of value for ornamental purposes; whilst the "amorphous" or vein-spar has only recently been recognized as a valuable commercial product.

It is interesting to find that Westgarth Forster, in 1821, gives a list of thirty-six lead-mines working, or having been worked, in Weardale, no less than twenty-five of which are stated to have fluorspar associated with the lead-ore.† Fluorspar was of no commercial value at that time; but the fact was mentioned, owing to this "vein" or "vein-stuff" being prominently associated with galena. At the present day, when fluorspar has a market value, with an improving trade, the information may be of interest to merchants and miners.

[redacted]

	Groverake Mine: Lump Spar. Per Cent.	Stanhopeburn Mine: Lump Spar. Per Cent.	Sedling Mine: Lump Spar. Per Cent.	Sedling Mine: Smalls. Per Cent.
Silica	traces	3·24	4·50	2·40
Calcium fluoride ...	93·68	96·06	91·51	93·89
Calcium chloride ...	traces	—	—	—
Barium fluoride	2·42	—	—	—
Barium sulphate ...	0·42	—	—	—
Oxides of iron	0·21	0·24	0·23	1·00
Alumina	0·29	0·36	0·12	0·35
Magnesia	0·23	traces	traces	traces
Phosphoric acid ... ... (=Phosphorus)	0·13 (0·056)	0·052 (0·023)	0·064 (0·028)	0·064 (0·028)
Organic matter	traces	—	*nil*	traces
Combined water	2·56	traces	0·75	1·05
Moisture	0·09	—	0·15	0·15
Oxide of manganese ...	—	traces	—	—
Sulphide of lead	—	0·086 (=Sulphur, 0·053)	1·85 (=Lead, 1·60)	0·47 (=Lead, 0·41)
Sulphide of zinc	—	0·126 (=Sulphur, 0·053)	0·83 (=Zinc, 0·56)	0·71 (=Zinc, 0·48)
	100·03	100·164	100·004	100·084

II.—Commercial Uses of Fluorspar.

Before referring to the present use of this mineral, as a most valuable flux, it may be interesting to refer to its early use in Weardale, where, at the lead-mines, for hundreds of years, fluorspar was abundantly produced in the process of mining for lead-ore, but only as a waste material. In early days, however, the vein-matrix or gangue of the lead-veins, pea spar-gravel, generally of a lightish grey colour, with a pinkish or faint-blue tinge, or with a purple or greenish tinge, and of a bright appearance, was a favourite material for garden-walks or footpaths, and hundreds of tons were used for this purpose. Spar-gravel was also, and is still, used on the outside walls of houses which are "slab-dashed" with fluorspar, that is, the walls, after being covered with lime, are sprinkled with spar-gravel, which is dashed or thrown on to the walls whilst the lime is yet soft, the particles of gravel sticking to the walls, which then present a covering, or coat, which in the sunshine has a beautiful and glittering effect. Many years ago, the writer knew a dwelling-house at Westgate, Weardale, called "Sparry Hall," the walls of which were treated in this manner. Sometimes the gravel is subjected to a general cement-wash, which gives the walls a grey and rough appearance.

Fluorspar in small quantities was dispatched from Weardale for use as a flux so early as the year 1847, and large quantities were, twenty years ago, sent to Scotland and America. Fig. 4 shows a heap of the mineral lying at Wearhead station.

Optical Properties.—It has been stated that transparent fluorite was sometimes used, on account of its optical properties, in the manufacture of microscope objectives and other refined optical instruments, but the writer was quite recently informed by an optician that he did not think fluorspar was ever used for this purpose.

Fluorspar as a Flux.—We are informed by Prof. Vivian B. Lewes that fluorspar has been used, from the earliest ages, as a flux in metallurgical processes.* It has been used, as is well known, in small quantities for the production of hydrofluoric acid for etching glass; it was also formerly employed in a secret process as a cleansing agent for castings, but is now being used as a valuable and general means for this purpose.

It is the high-grade fluorspar, namely, the pure white or pale blue, that is used for enamelling purposes, and in the manufacture of agate ware and opalescent or milky glass. It has also been used in the smelting of tin, copper, nickel, and lead, and for various other purposes.

Fluorspar and the Reduction of Lead.—Mr. W. S. Tangier Smith states that "fluorspar is used chiefly as a flux in the manufacture of steel and pig-iron, and to a minor extent in the reduction of lead."†

The fact that the mineral was used in England as a flux for the reduction of lead so long ago as 1730 is of interest, and, no doubt, it was employed long before that date. Dealing with mining operations in Derbyshire at that date, mention is made of a simple bloomery for the reduction of lead, as follows:—

"The furnace, which I saw near Worksworth, was very rude and simple, consisting only of some large rough stones, placed in such a manner as to form a square cavity, into which the ore and coals are thrown *stratum super stratum*; two great bellows continually blowing the fire, being moved alternately by water. I saw no other fuel used on this occasion but dried sticks, which they call white coal. . . . . They generally throw in some spar along with the ore, which is thought by imbibing the sulphur to make it flux more easily. They frequently throw in also some cowke (or cinders of pit-coal) because they think it attracts the dross, and so makes an easier separation of it from the lead. When the ore is melted, it runs out at an opening in the bottom part of the front of the furnace, through a small channel made for that purpose, into a cylindrical vessel, out of which it is ladled into the mould. The dross of the ore on smelting is called slag. This slag is afterwards smelted again with cowke only, and the lead obtained from it is called slag-lead."‡

* *Service Chemistry*, by Prof. Vivian B. Lewes, second edition, 1895, page 354.

† "The Lead, Zinc, and Fluorspar-deposits of Western Kentucky," by Messrs. E. O. Ulrich and W. S. Tangier Smith, *United States Geological Survey: Professional Papers*, No. 36, 1905, page 118.

‡ *The Philosophical Transactions* [*of the Royal Society*] (*from the Year 1719, to the Year 1733*) *Abridged and Disposed under General Heads*, by Messrs. John Eames and John Martyn, 1734, vol. vi., part ii., page 193; and *Memoirs of the Geological Survey of England and Wales: The Geology of the Carboniferous Limestone, Yoredale Rocks, and Millstone Grit of North Derbyshire*, by Messrs. A. H. Green, C. Le Neve Foster, and J. R. Dakyns, second edition, with additions by Messrs. A. H. Green and Aubrey Strahan, 1887, page 121.

Dr. R. Watson pays a tribute to fluorspar as a flux when he states that—

> "The lead-smelters [Derbyshire] make great use of the cubical spar as a flux for such lead-ores as do not readily melt: it is curious to see its effect; a few shovels full of it, thrown upon a heap of red hot ore, immediately melting down the ore into a liquid, though the longest continuation of the same degree of heat, without the addition of the spar, would not have been sufficient for the purpose."[*]

Perhaps its use in Derbyshire spread to other mining fields in the North of England. About 1857, or before, Mr. William Bolton, on the recommendation of the late Mr. Bainbridge of Middleton-in-Teesdale, used a little fluorspar in the reduction of lead at Dufton, Westmoreland; and it was thought by the writer's informant that Mr. Bainbridge might have seen it used in Derbyshire for the smelting of lead-ore.

Old smelters in the Allendale district do not know that fluorspar has ever been used for the reduction of lead, and the smelter at the Weardale Lead-mining Company, Limited's, smelting-mills, states that fluorspar acts as a flux in two ways: (1) by combining with silicates, forming fusible compounds, and (2) by reacting on silicates and evolving silicon fluoride. He states that it also forms fusible compounds with sulphates of lime and baryta, and with phosphates of lime; and it should be free from pyrites, blende, and galena. He mentions that in fume-smelting and slag-smelting a little of it acts beneficially, but he has not gained any advantage by its use in ore-smelting, [redacted]

so much so that a forecast might well be made that no mineral in the future will be of more value for the manufacture of steel, iron, and other metals. We find it stated that to metallurgical processes in dealing with refractory ores fluorite is especially adapted, owing to its fluidity in the formation of slag at a low temperature.

Mr. Joseph Hyde Pratt, referring to foundry-work, says, "for this purpose the fluorspar gives a much cleaner iron, and its demand should be almost unlimited as foundrymen become better acquainted with its value for use in their furnaces."*

Mr. Ernest F. Burchard, dealing with this subject, states that—

"The three principal classes of consumers of fluorspar are, in order of importance, smelters and metallurgists, makers of opalescent glass and enamelled wares, and chemical manufacturers. The highest grade, American lump No. 1, which runs less than 1 per cent. silica and is colourless or clear-blue in colour, is sold either ground or in lump, for use in the glass, enamelling, and chemical industries, the latter including the manufacture of hydrofluoric acid. The second grade, lump No. 2, is used by blast-furnaces in the production of ferrosilicon and ferromanganese, and in basic open-hearth steel-furnaces to give increased fluidity to the slag and to reduce the contents of phosphorus and sulphur. This grade includes coloured spar and may run as high as 4 per cent. silica, though mostly sold with a 3 per cent. guaranty. The lowest grade, gravel-spar, including all that contains more than 4 per cent. silica, as well as spar mixed with calcite, is used in iron and brass-foundries, where it is of value in making the metal more fluid, in permitting the use of greater quantities of lower grades and scrap, and because it carriss phosphorus, sulphur, and other impurities into the slag."†

Mr. F. Julius Fohs tells us that—

"Among the more recent applications of fluorspar to new uses may be mentioned: (*a*) In the reduction of aluminium from bauxite, a purpose for which the demand is likely to increase, at the same time causing a decrease in the importation of cryolite. (*b*) As a flux for gold ores, assisting in decreasing gold losses as in the Cripple Creek district. (*c*) As a bonding for constituents of emery-wheels. (*d*) For carbon electrodes, increasing their lighting efficiency and at the same time decreasing the amount of required current."‡

Mr. Fohs sums up the uses of fluorspar as being "dependent on its chemical composition, fluxing properties, phosphorescence upon heating, optical and pseudogem properties."§

Fluorspar is also used as a constituent in Portland cement.

* "Fluorspar and Cryolite," by Mr. Joseph Hyde Pratt, *United States Geological Survey: Mineral Resources of the United States*, 1904, page 1032.

† "The Production of Fluorspar and Cryolite in 1906," by Mr. Ernest F. Burchard, *United States Geological Survey: Mineral Resources of the United States*, 1907.

‡ "Fluorspar," by Mr. F. Julius Fohs, *The Engineering and Mining Journal* [New York], 1906, vol. lxxxi., page 46.

§ *Ibid.*

III.—Weardale Fluorspar.

Weardale Metalliferous Veins.—The mineral veins in Weardale, from a mineralogical point of view, may be divided into three classes, especially in considering fluorspar as a matrix:—(1) quartz-veins, (2) veins east of the Burtreeford fault, and (3) veins where fluorspar is not so prominent, namely, west of the Burtreeford fault. All these veins may carry lead-ore and rider or ironstone, but the principal point is to show where fluorite predominates.

(1) *Quartz-veins.*—It may be interesting to consider first the exceptional vein which runs from the Billing Hills eastward over Catterick and down to Bollihope burn, which it crosses at Bishopley Crags, showing two ribs of quartz standing out above the ordinary level of the water-bed. This vein is probably an extension or a string from the Great Sulphur vein of Alston Moor. As the Slitt vein crosses the Wear from the north side at Cammock Eales to Ludwell Wood, the quartz-vein is considered to be an extension, but Westgarth Forster favoured the view that the Catterick or Billing vein was connected with the great "backbone of England" as at Alston.* Between Billing Shields and Ludwell farms may be seen large pieces of quartz-vein matrix which have been used for building and coping the walls. In Stanhope and Frosterley, quantities of this quartz-vein matrix may be seen in borders and rockeries in front of the houses, and blocks of this quartz have also been freely used as rockeries [redacted]

fluorspar is somewhat rare, but that it must have been at one time very common, as it has left its traces as pseudomorphs in quartz after fluorspar.*

(2) *Veins East of the Burtreeford Fault.*—This district covers the parish of Stanhope, less the heather moorlands west of the Burtreeford fault, as Killhope, Wellhope, and Burnhope. This district is by far the most important, as it produces the whole of the commercial fluorite now being sent from Weardale. Through the kindness of Mr. Errington Thompson, chief agent of the Weardale Lead-mining Company, Limited, the writer has received from Mr. S. Walton, sub-agent, a list of the veins in this district, with their mineral contents, as follows:—

(*a*) *South-east Running Veins.*—Red vein: A strong master vein, 10 to 30 feet in width, running from Allenheads in the west to beyond Stanhope in the east; matrix, generally fluorspar, in some places rider (iron-ore), with large deposits of rider on the side of the fluorspar in the flats at Stanhopeburn mine. The vein also carries a large deposit of iron-ore in Rookhope.

Sedling vein: A strong vein, 8 to 15 feet in width; matrix, fluorspar of good quality; other minerals present are galena, arsenical pyrites, quartz, etc.

Slitt vein: A strong master vein, 10 to 20 feet in width, running into the Burtreeford fault westward and beyond Harehope gill to the east; matrix, generally fluorspar; has been very productive of lead-ore at Elmford, and at the Slitt mine, where it was worked through the Whin Sill.

(*b*) *East-north-east Running Veins.*—Green Cleugh vein: 4 to 6 feet in width; matrix, fluorspar, with lead-ore and also quartz.

Groverake vein: 10 to 20 feet in width; matrix, fluorspar, with lead-ore and, in places, copper pyrites.

Wolf Cleugh vein: 4 to 10 feet in width; matrix, very white fluorspar, with lead-ore, and also carbonate of iron and arsenical pyrites.

Rispey vein: 3 to 4 feet in width; matrix, fluorspar, with lead-ore and carbonate of iron.

Boltsburn vein: 4 to 6 feet in width; matrix, fluorspar, with lead-ore; large flats on both sides of the vein in the Great Lime-

* *The Laws which Regulate the Deposition of Lead-ore in Veins*, by Mr. William Wallace, 1861, page 143.

stone, with large formation of fluorspar crystals in loughs or small cavities; colour, various shades of mauve, violet, blue, and purple; loose blocks or cubes, the residuum of decomposition; calcite in form of stalagmites; carbonate of iron coating galena; quartz, blende, iron pyrites.

Thorny Brow vein: 3 to 4 feet in width; matrix, fluorspar, with lead-ore; formerly productive of lead-ore.

Brandon Walls vein: 3 to 4 feet in width; matrix, fluorspar, with lead-ore.

Scar Syke vein: Matrix, fluorspar, with lead-ore.

Middlehope Shield vein: Matrix, fluorspar, with lead-ore, with fluorspar in druses and single cubes of a beautiful green.

Heights vein: Matrix, fluorspar, with lead-ore, and fine green fluorite in the flats.

Breckon Syke vein: 6 to 12 feet in width; matrix, fluorspar, with lead-ore. This vein runs into Allendale, where it is known as Henry's vein.

Burtree Pasture vein: 6 to 12 feet feet in width; matrix, fluorspar, with lead-ore; level, 2½ miles long, with a 200-fathom vertical air-shaft, from the Whin-sill to the Grindstone-sill.

Wearhead vein: Matrix, fluorspar, with lead-ore.

Black Dene vein: 3 to 5 feet in width; matrix, fluorspar, with lead-ore.

Lodge Field vein: 3 to 5 feet in width; matrix, fluorspar, with lead-ore.

[redacted]

Swinhope Cross vein: A strong fluorspar-vein.

Barbara vein: Matrix, fluorspar.

(c) *Bollihope Veins.*—(1) Yew-tree vein: Matrix, fluorspar; formerly productive of lead-ore in the firestone, which is here 16 fathoms thick. (2) Whitfield Brow copper-vein: Matrix, fluorspar; formerly productive of lead-ore. (3) Cornish Hush vein: Matrix, fluorspar; formerly productive of lead-ore. (4) Harehope Gill, Softley, and Park Level veins all contained fluorspar.

(3) *Veins West of the Burtreeford Fault.*—These veins are not favourable for the production of fluorspar. The writer is indebted to Mr. John Thompson, sub-agent, Weardale Lead-mining Company, Limited, for particulars of the following principal veins in the Burnhope and Killhope district:—

Killhope Head vein: 4 to 6 feet in width; matrix, rider, amber, light-blue, and some dull-green fluorspar; "Black Jack" or zinc-blende and lead-ore.

Level Grove vein: 2 to 3 feet in width; formerly productive of lead-ore; rich in extension flats, rider, and a little fluorspar.

Tweed vein: 3 feet in width; matrix, rider; formerly productive of lead-ore.

Old Moss vein: 2 to 3 feet in width; matrix, rider, iron pyrites, lead-ore, and a little fluorspar.

Middle Grove vein: 3 to 4 feet in width; matrix, rider, a little fluorspar, a good deal of "Black Jack," and lead-ore.

Hymers vein, or Park Level: Matrix, rider; herring-bone strings of lead-ore.

Lodge Gill vein: 3 to 4 feet in width; matrix, rider; very little fluorspar.

IV.—Bibliography.

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Ure, Andrew, *A Dictionary of Chemistry and Mineralogy*, 1831, page 472.

Watson, Thomas, "Lead and Zinc-deposits of Virginia," *Virginia Geological* [redacted]

Mr. F. W. Rudler (London) wrote that it might not be without interest to call attention to the fact that the late Prof. M. Berthelot undertook some experiments on the colour of the violet fluorspar from Weardale, which have been continued by his son, Prof. Daniel Berthelot. The colour was first discharged from the mineral by the application of heat, and the decolourised fluorspar was then exposed to the prolonged action of a compound of radium, when it was found that the violet tint was gradually restored. It would thus seem possible that the natural colour of fluorspar might be largely influenced by the radioactive matter in the neighbouring rocks, as Prof. Bordas had suggested with regard to coloured corundums. The effect was believed to be due to the *gamma* rays emitted by radium, which had great penetrating power, and might perhaps act specially along the cleavage-planes. In connection with Mr. Egglestone's remarks on the varied colours of fluorspar, it might be mentioned that a large suite of specimens was arranged in the Museum of Practical Geology, London, showing that this species presented nearly all the tints of the rainbow. The octahedral cleavage-cracks, produced by a mere tap on a crystal, often increased its beauty by giving rise to interference-colours from the very thin films of included air. It had been held with much probability that the material of the famous Murrhine vases, so highly valued in Rome, whither they were first brought by Pompey, must have been a purple fluorspar showing iridescence, as described by Pliny. Mr. Egglestone referred to the use of ornamental fluorspar by pre-historic races, and it might therefore be interesting to recall the fact that Dr. E. Dupont, of Brussels, discovered more than forty years ago a limestone-cavern on the bank of the River Lesse, from which he obtained a collection of fossil-shells brought from a distance, with other curious objects, including a piece of fluorspar. They might have been accumulated for purpose of worship, or simply for personal decoration, but it had also been suggested that they were collected as mere curiosities, and, if so, we had here a specimen of fluorspar from a pre-historic museum.

Councillor J. T. Biggs, J.P. (Chairman of the Museum and Art Gallery Committee, Leicester), wrote that he considered Mr. Egglestone's interesting paper a most valuable contribution to

the subject. It might probably interest the members to know that there was a very fine example of a "Blue John" vase in the Leicester museum, the basin of which measured 12 or 13 inches across. The museum also contained some very fine fluorspar cubes, richly irridescent, which he (Mr. Biggs) had obtained from Weardale, in which district he had seen magnificent cubes measuring as much as 8 or 10 inches, and fluorspar in every variety of colour. The commercial value and uses of fluorspar were likely to considerably appreciate in the near future.

Mr. J. H. Collins (London) wrote that it would probably interest the members to know that, twenty years ago, the uncleavable and highly phosphorescent variety of fluorspar—chlorophane—which yields a bright green light when moderately heated, was rather abundantly found in the Great Lode at East Pool (Cornwall). He might also say that purple fluorspar occurred as a constituent of the granite, and also as a coating of minute cubes in the joints thereof, at Wheal Damsel, and other places in Cornwall. It also occurred similarly in the chinastone of St. Stephens and St. Dennis in Cornwall, and at Montebras in Central France.

Mr. S. Watson (Ireshopeburn, Weardale) wrote that the Weardale fluorspar-veins did not appear to be influenced by the adjacent rocks or walls. The mineral was as plentiful in siliceous as in calcareous rock, differing in that respect from its associated mineral, galena, which was generally more abundant in the latter.

[redacted]

Mr. B. L. Bradley (Grindleford) wrote that he had read Mr. Egglestone's paper with considerable interest, as his duties brought him constantly in touch with lead and spar-mining operations in Derbyshire. He congratulated Mr. Egglestone on the able manner in which he had tackled so difficult a subject; not only from an engineering and geological standpoint, but also from the chemical and commercial side, and his knowledge of the subject was so full, that he had scarcely left a loophole for argument.

With respect to the chief Derbyshire deposits, the best were to be found in North-west Derbyshire, of which the main were the Moorfurlong pipe and cross-cuts in the Bradwell district, and the High and Deep Rakes in the Longstone district. "Blue John" was found in varying quantities, but not to any great extent; the shade of the heavy deposits was generally pale pink, although sometimes the mineral occurred as a colourless crystal; the sides of the cubes rarely exceeding ⅜ inch. The pipes were ellipsoidal, the fluorspar lying convex to the transverse axis, but sometimes alternating with layers of barium sulphate and limestone; the fluor-beds varied in depth from 1½ to 10 feet. The thickness of the fluorspar in the master-veins was from 3 to 12 feet, and occasionally reached 15 feet; and in the cross-cuts the thickness was from 1 to 3 feet.

With regard to the commercial side of the paper, he quite agreed with the author that the Weardale and the Allendale fluorspars were excellent, and he thought that they were ahead of the spars in the Derbyshire district as regarded beauty and symmetry of form, when taken in bulk; yet he might say that there existed excellent specimens of modelled fluorspar made of the "Blue John" of Derbyshire, which were fine works of handicraft and art. A fine polished pillar and pedestal of "Blue John" stood in the mineral-room of Chatsworth House, and in the writer's opinion, as well as that of others better able to judge, this work excelled many others of similar design in Grecian marble. Of late years, however, very little had been done in fluorspar-modelling, owing to the increased export of the mineral for smelting industries. As a flux, taking the spar *en masse*, he was of opinion that the Derbyshire deposits were preferable; and this opinion had been confirmed by practical steel-producers and others engaged in smelting. This opinion was based

upon the following points:—(1) Derbyshire fluorspar was freer from sulphides, thereby reducing the sulphur, and also contained less silica; and (2) owing to its soft nature, it did its work more quickly. Records showed that fluorspar had been used as a flux before 1730. He had seen one record, made by a Mr. Hawes when touring this country prospecting for minerals on behalf of Spaniards in the year 1800, which contained the following remark:—"I noticed at Castletown [Castleton], in Derbyshire, that the metal-smelters used a flux known as 'smelting sugar,'* which was also called 'Blue John.'"†

Mr. W. M. Egglestone (Stanhope) wrote that he was glad to know that his paper on fluorspar had been of some interest to the members of the Institute, and he welcomed with much pleasure the remarks of Mr. Rudler and others on some additional properties of that beautiful mineral.

With reference to Mr. Watson's remarks that "he (Mr. Watson) scarcely thought that the author was justified in assuming that the ironstone deposits on the side of the Weardale veins were evidence of enrichment from the veins," and that "the fissuring of the rocks, tapping the ferruginous solutions of the shale-beds, would provide an adequate supply,"‡ he (Mr. Egglestone) was of opinion that he was, from good authority, justified in assuming that "the metasomatic action which converted the limestone into ironstone is evidence of rock enrichment from the metalliferous vein,"§ and would state that the

[redacted]

Scar Limestone was a vein of brown iron-ore from 16 to 20 feet wide. The Manor House vein, near Alston railway station, was 14 feet wide, and from wall to wall produced nothing but this kind of ore. In the veins in Killhope (Weardale), it was stated, were found corals, characteristic of this formation, enveloped and entirely fossilised in brown iron-ore, and it was noted that a curious series of changes had probably operated on the fossiliferous limestone which at one time formed the walls or sides of the vein (metasomatic action). In Stanhopeburn the veins were so charged with this iron-ore that a large area of ground was bodily removed by the Weardale Iron Company, and a considerable quantity of lead ore was separated during the operation. The Rispey vein in Rookhope contained this brown peroxide of iron spreading over a width of 30 to 40 feet. It was considered that brown iron-ore was due to the decomposition and that it was originally placed *in situ* in the conditions as a carbonate. Mr. Kendall has pointed out that this ore or rider assumes two forms, first as ribs from a few inches to 20 feet in width and that if one of the sides or walls of the vein is limestone and the other sandstone, the ribs of iron-ore are to be found on the limestone wall; if both are limestone, iron-ore is found on both walls, and where the iron-ore adjoins the limestone there is a gradual passage from one to the other, that is, from ore to limestone and limestone to ore.* The same writer, referring to the limonites and siderites of Weardale and Alston, says—" There cannot be any doubt that the siderite, which was the original ore here, and from which the limonite was produced by alteration, was formed by the replacement of limestone. The growing together of the two minerals, where they are in contact, is alone sufficient to prove this."† As to where the original iron which filled the veins came from is another matter, and an important one. The Coal-measures, which constitute a considerable storehouse of iron-ore, have been mentioned; also the Permian rocks, and the Carboniferous Limestone shales, as above mentioned, which are depositing limonite at the present day. Then there are the thermal springs and the influence of igneous rock, as also the introduction of iron in a gaseous form from deep-seated sources.

* *The Iron-ores of Great Britain and Ireland*, by Mr. J. D. Kendall, 1893, page 142.

† *Ibid.*, page 327.

It may be mentioned that the author of *A Manual of Mineralogy*, dealing with the minerals of Cornwall, 1825, states that the most beautiful varieties of fluorspar in that district had been found at St. Agnes, and one purple specimen, in crystallised cubes, had "every plane or face exhibiting a flat four-sided pyramid, so as to form a solid, bounded by 24 triangular planes,"* and that chlorophane of a violet-blue colour, and which threw out a beautiful emerald-green colour when heated, had been found in Pednandrae Mine, Redruth. Mawe mentions blue fluorspar with four-sided pyramids on each face, and also crystals with enclosures and bevelled edges.†

Mr. Egglestone, in conclusion, thanked the President and members for their unanimous vote of thanks, and wished also to express his obligations to Mr. Lawrence Austin for the courteous assistance rendered to him by that gentleman in the preparation of the paper.

On the motion of the PRESIDENT, a vote of thanks was unanimously passed to the writer of the paper.

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MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS AND THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

JOINT GENERAL MEETING,
HELD IN THE GENERAL LECTURE ROOM, THE UNIVERSITY, SHEFFIELD,
APRIL 7TH, 1908.

MR. W. WALKER (PRESIDENT OF THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS), IN THE CHAIR.

The following gentlemen, having been previously nominated, were elected members of the Midland Institute of Mining, Civil and Mechanical Engineers.

MEMBER—
Mr. WILLIAM LANG, Electrical Engineer, 18, Louis Street, Chapeltown, Leeds.

STUDENTS—
Mr. WILFRED SPENCER ELLIS, Mining Pupil, Nostell Colliery, near Wakefield.
Mr. GEORGE FORSTER, Colliery Pupil, Hope Villa, Highgreen, near Sheffield.

The following gentlemen, having been previously nominated, were elected members of The Midland Counties Institution of Engineers:—

MEMBERS—
Mr. HUBERT ORMOND BISHOP, Colliery Manager, Nuttall's Park, Ripley, Derby.
Mr. DANIEL DAVIES, County Mining Lecturer, 45, Broniestyn Terrace, Aberdare, South Wales.
Mr. CHARLES MAXTED HASLAM, Mining Engineer, Pentrich Colliery, near Alfreton.
Mr. GRANT FREDERICK GUEST SCOTT, Chief Mining Engineer, The Bengal Coal Company, Limited, 5, Fairlie Place, Calcutta, India.

ASSOCIATE—
Mr. WILLIAM L. REID, Draughtsman, Woodthorpe, Norbriggs, Chesterfield.

STUDENTS—
Mr. SHIRLEY ONSLOW LIMBY, Assistant Manager, c/o Messrs. Atkinson & Dallas, 4, Peking Road, Shanghai, China.

Mr. HORACE SHACKLETON, Mining Student, London Road, Coalville, near Leicester.

Mr. PERCIVAL RICHARD SMITH, Mining Pupil, Manners Colliery, Ilkeston.

Mr. THOMAS WHARTON, Assistant Manager, Netherton House, Glapwell, Chesterfield.

Mr. WILLIAM ROBERT WILSON, Mining Pupil, Tuxford Hall, Tuxford, near Newark.

The CHAIRMAN (Mr. W. Walker) congratulated Prof. R. A. S. Redmayne on his appointment to the post of Chief Inspector of Mines, and hoped that he might have health and strength to perform satisfactorily the duties appertaining to his new office.

Mr. G. J. BINNS (Derby), on behalf of The Midland Counties Institution of Engineers, joined in the congratulations.

Prof. R. A. S. REDMAYNE suitably replied.

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FENCE-GATES FOR PIT-CAGES.

By W. H. PICKERING.

A prejudice, which the writer admits he shared for many years, against fencing the ends of pit-cages has been common to mining engineers and working miners. The attrition of time and of changed conditions appears to be slowly removing that prejudice, and the moment seems to have arrived when the question can be profitably discussed by this Institute. The question is not so simple as it appears on the surface, for it covers many debatable points upon which it is desirable that the fresh air of discussion should blow.

Recently, the writer issued a semi-official circular to the Yorkshire mine-owners, suggesting that attention should be given to fencing the ends of cages. The result has been that in many cases more or less satisfactory gates have been fixed, but public opinion is by no means unanimous. The writer has made enquiries from other districts, and finds that although bars and chains are used in many instances, gates are very exceptional. In some districts, fences of any description at the ends of the cages are almost unknown. Most attention seems to have been paid to the subject in the Yorkshire, Derbyshire, and Nottingham coal-field, of which Sheffield is the centre.

The senior inspectors of mines are, perhaps, in the best position to give opinions on the subject, and it is somewhat embarrassing to find that they disagree. Two extracts from recent official reports may be given. Mr. J. B. Atkinson, in his annual report for the year 1904, writes as follows:—*

"In connection with accidents Nos. 23 and 24 there was some discussion at the inquests (which were held by different coroners and juries) as to the desirability of closing the ends of cages while persons are ascending or

* *Report of Mr. J. B. Atkinson, H.M. Inspector of Mines for the Newcastle District (No. 3), to His Majesty's Secretary of State for the Home Department, under the Coal-mines Regulation Acts, 1887 to 1896, the Metalliferous-mines Regulation Acts, 1872 and 1875, and the Quarries Act, 1894, for the Year 1904*, page 17.

descending, and one of the juries added a rider to their verdict recommending the adoption of such a precaution. I brought the matter before my colleagues at our annual meeting in May last, but it did not appear that it is at all a general custom in any district to close the ends of cages, although it is done at a few collieries. Very few accidents happen to persons ascending or descending shafts in cages, and as it is very probable that the general adoption of doors or gates would lead to some accidents, I am not prepared to recommend their use."

Mr. A. H. Stokes, commenting on shaft-accidents in his annual report for the year 1905, says:—*

"It is absolutely necessary that all cages should be fenced at both ends when men are riding, and such fence should be rigid and not likely to give way upon being slightly moved during the ascent or descent of workmen. There are several ways of doing this, some ingenious and effective, others not so satisfactory. So far as I know, every cage in the district uses a fence when men ride, and I trust this accident will bring before all managers the importance of not adopting a fence which may be moved by any slight oscillation or movement of men when riding in the shaft, but that a rigid bar is adopted which may not be accidentally released during the progress of men through the shaft."

Substantial gates at the ends of cages would undoubtedly have directly saved lives during the past few years.

The following cases of fatal accidents are taken from the annual reports of H. M. Inspectors of Mines:—

Year 1902.—One man was thrown out of the cage when it was suddenly raised.

Two men were thrown down the shaft through the cage leaving the guides and tilting.

One man fell from the cage whilst ascending.

[redacted]

A manager and under-manager were thrown out of the ascending cage during a collision in mid-shaft.

A descending cage, containing twenty-eight persons, struck an iron girder. Two persons were thrown down the shaft.

One man fell down a shaft, owing to the cage tilting.

Year 1904.—One man fell from the cage whilst ascending, after complaining of illness. The jury in their verdict recommended gates for the ends of cages.

One man fell from the cage whilst ascending with others; he occupied the outside position.

A panic occurred in a cage in which twelve persons were riding. Two jumped out, and were killed.

A master wasteman was killed whilst ascending alone.

A deputy fell from the cage whilst ascending alone.

One man was thrown out of the cage when descending a shaft with five others, the cage having struck a bearer.

One man stepped off the cage at a mid-inset, and fell down the shaft. He probably thought that he had reached the shaft-bottom.

Six men were descending when the cage left the guides, tilted, and threw three of the occupants down the shaft.

One man was crushed when attempting to enter the cage after it had left the surface.

One man was crushed when attempting to enter the cage as it was leaving the pit-bottom.

One man fell from the cage whilst ascending, after feeling unwell.

Year 1905.—One man fell from the cage whilst ascending with seven others.

A man, who was supposed to have fainted, fell from an ascending cage.

One man fell from the ascending cage.

One man fell from the descending cage. The jury in their verdict recommended the use of protective gates.

One man fell from the cage whilst ascending.

One man jumped out of the ascending cage in a panic.

Year 1906.—One man was crushed whilst descending a shaft.

One man was thrown out and another crushed when a descending cage, containing thirteen persons, was jerked and improperly run by the engine-man.

One man was crushed by stepping off the cage by mistake before it reached the surface.

One man, who was subject to fits, fell from the cage in which he was riding with several others.

One man was killed when attempting to enter a moving cage at the pit-bottom.

Two men jumped from a cage in a panic. The cage containing twenty-two persons had just left the pit-bottom.

One man fell, or jumped, from a cage in which he was being raised with four others.

One man fell from the cage when ascending with four others.

The writer has considered it advisable not to give any instances for the year 1907, as the full reports of the accidents

are not yet published, but a glance at the following table will show that there is a bad record for that year.

NUMBER OF DEATHS FROM SHAFT-ACCIDENTS DURING THE YEARS 1902 TO 1907 INCLUSIVE.

Year.		Total Deaths.		Deaths whilst Ascending or Descending.
1902	...	102	...	21
1903	...	69	...	20
1904	...	82	...	26
1905	...	65	...	13
1906	...	68	...	13
1907	...	97	...	36
Total	...	483	...	129

The loss of life whilst ascending or descending is small when the large number of cage-journeys necessary to raise and lower the underground workers, who numbered 662,901 in 1902, and 757,887 in 1907, is considered. If allowance be made for the persons who walk in-bye by drifts, and for those off work, perhaps 500,000 will remain who are raised and lowered in cages daily. If eight be taken as the average cage-load, we arrive at the figure of over 60,000 double-cage journeys a day.

In the opinion of the writer, the time is arriving when danger in shafts will increase very seriously, unless steps be taken to meet the changed conditions. Every intelligent observer will admit that the rapid means of communication throughout the world have changed the conception of what is the right aspect [redacted]

large cages. Every effort will have to be made to get men quickly to and from their work. Already there are instances where eighty men ride in the shaft at one time, and at a speed of 40 miles an hour. Under such conditions, a single man falling from the cage might cause a disastrous accident to all the men in the shaft, the cause of which might never be made clear.

The writer is in favour of allowing a large number of men to be raised together, for although, theoretically, there will be the same average risk over a number of years, whether the men are raised by tens or by twenties in a cage, still the larger number allows less margin for human error. With a larger number in a cage, there is more time to get the men up and down the pit, there is necessarily more deliberation in marshalling them in the cage, and the engineman, banksman, and onsetter have more time to realize what they are doing. Effective cage-gates will allow more men to be safely raised at one time, and will ensure proper order at the pit-top and pit-bottom.

The safety of property is also well worth consideration. There are no records of accidents which cause no personal injury or loss of life; but there are few mining men who could not give instances of very serious damage to shafts and equipment by tubs falling from the cages. Gates in certain cases can be designed so as to help to prevent such accidents. The writer submits that an ideal gate should (1) be automatic, (2) be simple in action and construction, (3) be of use when coal is being drawn, (4) have no projections into the shaft, (5) be incapable of opening outwards into the shaft, and (6) be able to stand the impact of a collision.

The writer is aware that it is quite impossible to devise a gate to suit all cages. In some cases a simple arrangement of fencing worked by hand will be sufficient; in others, more elaborate automatic gates are desirable. The gates should be made to fit the conditions, and not the conditions to fit the gates.

Mining engineers have not made sufficient use of the back-shafts or second outlets. The Coal-mines Regulations Acts require that apparatus for raising or lowering men shall be kept at such shafts,* but in many cases such apparatus is of a make-

* *Coal-mines Regulation Acts*, 1887-1896, section 16, sub-section 1(*c*).

shift description, and is useless except for emergency-riding. Attention might reasonably be given to these shafts, for in many cases it would pay to equip them with proper engines and cages for raising and lowering the men daily. The provision of satisfactory gates for cages used exclusively for raising or lowering men is comparatively simple.

To summarize, the writer is of opinion that cage-gates should be provided for the following reasons:—

(1) To meet the different conditions of work into which we are passing.

(2) To prevent persons falling from cages from illness, panic, collisions, or hurry.

(3) To prevent disorder and confusion.

(4) To enable more persons to be raised safely each journey.

(5) To prevent damage to the shaft and shaft-fittings by tubs falling from the cages.

The appendix attached to the paper contains brief descriptions of several of the fence-gates exhibited at the meeting.

APPENDIX.—DESCRIPTIONS OF VARIOUS FENCE-GATES FOR PIT-CAGES.

The Chambers Automatic Fence-gates (figs. 1, 2, and 3, plate xi.).—This arrangement consists of a number of bars, which are automatically lowered as the cage leaves either the pit-bottom or the top by a combination of levers and pulleys actuated by the arm, *A*, engaging with an inclined fixed girder, *G* (fig. 1). The bars are automatically raised when the cage is at the landings. Fig. 1 is a side elevation, whilst figs. 2 and 3 show respectively the cage closed

[redacted]

gate are:—(1) its perfect simplicity in make and action; (2) its compactness when out of service, the width of the lattices when held by the catch at the top being only about 3½ inches; and (3) its adaptability to any pit-cage, no locking arrangements being required. There are no intricate working-parts to get out of order by clogging, etc., and no skilled labour is required to work the gate. It can be opened or closed easily from either the inside or the outside of the cage by a man or a youth, as its total weight to lift is only about 15 pounds. The catch at the top is so arranged that when the gate is pressed to its out-of-service position, it automatically catches a stud on the bottom picket, and is held there. It is just as easily released when it falls by its own weight into its service position; when within 8 or 9 inches from the ground, it comes into contact with a spring fixed in the channel of the guide-bars on either side to take the dead-weight of the fall and to prevent the gate clashing. It is quite strong enough to form an absolute guard against any person falling from the cage.

The "Simplex" safety-cage (figs. 20, 21, and 22, plate xii.) is specially constructed for use in pit-cages which have corve-catches fixed at the side and where the only framework to which the guard can be fixed is at the top of the cage. The framework is composed of two slides formed of steel channels fixed to the upper portion of the cage. The gate is made of horizontal bars, ½ inch in diameter, placed about 9 inches apart, riveted to flat bars forming the slide-bars, and hinged on studs at each side and on the top of the gate, with a lock placed in an accessible position to secure the gates when in service-position and when out of service-position.

The Gill Collapsible Fence-gate (figs. 6, 7, 8, 9, and 10, plate xi.).—These gates may be worked either by hand or automatically. When manipulated by hand, and men are about to enter the cage at the surface, the banksman draws up the gate by means of the handle and chain, *J* (figs. 6 and 7). In this position they are securely held by the ratchet wheel, *K*, and pawl, *L* (fig. 6). As soon as the men have entered the cage, the pawl, *L*, is lifted, when the gates fall into the position shown in fig. 7. If necessary, a small band-brake, *M* (figs. 6 and 7), may be attached to the pawl, *L* (fig. 6) to steady the gates in falling. When the cage with its complement of men arrives at the landing at which the men are to alight, and the cage is about 1 foot from its stopping-place, the handle and chain, *J*, come within reach of the onsetter, who, by the means before described, raises the gates while the cage comes to rest, ready for the men to walk out of it. If the cage is returned to the surface empty, the gate is left in the open position, and only closed by the banksman after reaching the surface, and again loaded with men. When winding coal, the gates are open and rest on bolts, *RR* (fig. 6), to relieve the stress on the working parts of the gates. When manipulated automatically, the shaft, *N*, of the roller, *H* (fig. 8), passes through the cage-side; secured to it is a wheel, *O*, which on approaching a landing comes into contact with a balanced rubber, *P*, fixed to the guider or a frame at each landing (figs. 9 and 10), which forces the wheel to revolve and wind up the gate. As soon as the cage starts on its return journey, the action of the roller is reversed, thus closing the gate. In case of an overwind, the gate closes automatically as soon as the cage gets about 2 feet too high, but the distance may be regulated as required. Should it be desirable to close the gate before withdrawing the fallers, or before the cage leaves the pit-bottom or any landing, this may be done by drawing back the balanced rubber with the rope or lever, *S* (figs. 9 and 10), when the gate falls into the closed position. To prevent gates opening and closing when passing intermediate landing places, the balanced rub-

bers are fastened back by means of a catch; but when the cage is required to stop at any particular landing, the rubbers at that landing are released, thus putting them into action, opening and closing the gates as desired.

The Botterill Automatic Pit-cage Gate (figs. 11, 12, 13, and 14, plate xi.).—This gate is built of strong block-link chains, *D* (fig. 11), working in shallow grooves fixed close to the inside of the cage at either sides, and rods or pipes, *E* (fig. 14), are fixed to the block chain about 8 inches apart, so as to form a strong barrier, flexible in one direction and somewhat similar to a roller-shutter. The shallow slides extend round a quarter of a circle at the top and straight on under the inside of the roof of the cage, so that when the gate is lifted by the motion it passes up vertically, then round the curve to a horizontal position, thus being out of the way. At a convenient point, a horizontal shaft is fixed just under the gate-slides, carrying two sprocket-pinions, *AA*, inside the cage, which latter engaged with the block chain of the gate, and on the outside of the cage another sprocket-wheel is keyed on to the same shaft. Vertically underneath the outside sprocket-wheel, is another idle sprocket-wheel, *C* (figs. 13 and 14), and around these two wheels the roller-chain runs; on this chain four projecting arms are attached in such a position that two will engage with a fixed stop-pin for opening and closing the gate when the cage arrives at the surface, the other two arms performing the same service when the cage arrives at the bottom of the pit. The action of the gate is such that when the cage is level or above the surface, the gate is up and out of the way; as soon as the cage commences to descend, the upper arm on one side of the roller-chain engages with the stop-pin, and as the cage travels it causes the roller-chain to revolve the sprocket-wheels, thus winding the gate down and closing the ends of the cage. When the cage has nearly reached the bottom, the upper arm on the other side of the roller-chain engages with a fixed stop-pin and winds the gate up again. As the cage ascends, the lower arm shuts the gate and the lower arm at the other side of the chain opens it again at the top. A wooden block shod with iron is fixed between the two sprocket-wheels to prevent the chain from sagging, and the idle sprocket-wheel near the bottom of the cage has an adjusting [redacted]

cage is fixed a shaft, on which are mounted drums of varying diameter, the number varying according to the number of bars constituting the fence or gate. On one end of this shaft is a pinion-wheel, which gears into fixed tooth-racks at the top and bottom of the pit-shaft. In the case of the cage approaching the pit-top or the pit-bottom, the pinion-wheel comes into gear with the toothed rack, and thereby the drums on the shaft are caused to rotate. Attached to these drums are flexible ropes, passing over pulleys at the ends of the cage, on which ropes the bars forming the fence are suspended. As all the drums commence to rotate at the same time, it is evident that each of the bars forming the fence commences to lift at the same time, so that there is no danger of anyone who is riding in the cage getting trapped between the bars, whilst owing to the different diameters of the drums the whole of the bars forming the fence arrive at the top at the same time. In case the cage goes too far, and is taken up into the headgear, provision is made by means of a second rack to reverse the direction in which the pinion-wheel is revolving, so that the fence is automatically lowered. To ensure the pinion-wheel gearing accurately with the toothed racks at the top and bottom of the pit-shaft, there is a flat on the drum-shaft upon which a stiff spring acts. This ensures the drum-shaft, and consequently the pinion-wheel, being in the exact position to enable the rack and pinion to come into gear with absolute accuracy each time.

The Richardson Cage-gates (fig. 23, plate xii.).—This fence, which is in use at the Barrow collieries, consists of three horizontal bars, *A*, sliding on vertical rods, *B*, provided with stops at suitable distances. The vertical rods are hinged at the top so that they may be raised to the top of the cage carrying the horizontal bars with them, and secured there with a bolt when the fence is not required. When the fence is in use, the vertical rods fall into slots at the cage-bottom, and are secured with small vertical bolts. This fence is worked by hand, and is not intended to be used when coal is being drawn.

The Houghton Fence-gate.—A description of this gate, with illustrations, has already appeared in the *Transactions*.*

The Hollings Tub-controller or Lock-catch.—This is specially adapted for pit-cages. The corves are secured by a catch which engages the axle of the corves. The lock is connected to a bar-lever, which is automatically locked, thus being doubly secure and preventing the release of the tubs by vibration. When applied to landings, etc., a hand-lever is added, which is arranged to lock itself, to guard against the danger of its being left out of action. Any one corf, or any number of corves, can be secured or released at will.

The CHAIRMAN (Mr. W. Walker) said that most of the members either did not approve of cage-gates at all or were just beginning to believe in them. He had for some time thought that there should be some protection against men falling out of cages, as he had in his official capacity investigated many cases where men or boys had taken a fit, or from some other cause had fallen out of the cage, and been killed. With any of the arrangements that had been des-

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., pages 326 to 328.

cribed, this would not be possible. Referring to the extract from Mr. J. B. Atkinson's report alluded to by the writer of the paper, he (Mr. Walker) thought that probably what Mr. Atkinson meant was that he did not believe in the ends of cages being absolutely closed up. Such an arrangement would be the greatest possible mistake. It had been argued that cage-gates would seriously handicap the output of a colliery, but he thought that there were gentlemen present at that meeting who were actually using gates, and who would tell them that such was not the case, particularly if automatic gates were used. By the adoption of automatic gates, it had also been found out that certain irregularities occurred in the shafts of which they were not before aware. Long timber, for instance, damaged the gates. In the old days it probably, unknown to anyone, caused damage to the fittings of the shaft, and from that point of view alone the advent of gates was perhaps a blessing in disguise. He moved a vote of thanks to Mr. Pickering for his admirable paper, as also to the gentlemen who had so kindly explained the working of the models of the cage-gates exhibited at that meeting.

Mr. John Gerrard (H.M. Inspector of Mines, Worsley) seconded the vote of thanks.

Mr. A. H. Stokes (H.M. Inspector of Mines, Derby) said that it was curious how, on looking at what one had written several years ago, one often was inclined to find fault with it. The last line [redacted]

Mr. Roslyn Holiday (Ackton Hall Colliery) said that one point upon which colliery-proprietors and inspectors had been unanimous was that gates should be made to fit the conditions, and not the conditions to fit the gates. This was one of the greatest difficulties with which they had to contend in dealing with such a question. Some of the models which had been shown to them, whilst very good under certain conditions, were not so under others. The gates which moved in grooves would probably work satisfactorily at first; but they had to bear in mind that a cage in ordinary use gradually opened out, which would allow the gates to come out of the grooves. Gates which moved up and down standards had an advantage in this respect; but in the cages of many pits there was no room for standards—in fact, the tubs could only just scrape in.

Mr. E. W. Thirkell (Aldwarke Main Colliery) said that at the colliery under his charge they had a gate worked by hand, and not automatically; and from what he had heard and seen that afternoon he preferred to have a gate worked by hand to one that was worked automatically.

Mr. Isaac Hodges (Whitwood, Normanton) said that he was originally of the opinion that cage-gates were not necessary, by reason of the abnormally small percentage of accidents that had occurred during winding. The collieries with which he was connected had been running over half-a-century, and were now lowering and raising from shafts 450 to 1,500 feet deep 3,000 men per day, and they had yet to have their first winding accident involving loss of life. However, after Mr. Pickering had pointed out the variety of accidents that had occurred during the winding of men, he had decided to look into the question and had inspected Mr. Gill's model at work. He was struck with the ease with which the gate was fitted to the cage, its simplicity, and small cost, and with the fact that it was practically no hindrance during the winding of coal; but he was of Mr. Thirkell's opinion that the gate should not be automatic. He thought it better that the cage should not be put in motion until the gates had been closed, which appeared to be impossible if the opening and closing of the gates depended on an automatic contrivance, as that would still allow some of the accidents mentioned by Mr. Pickering to occur. At the time that he saw Mr. Gill's model, it

was worked by the banksman, and he had come to the conclusion that that method was more certain and easier of adoption than if made to depend on mechanical means.

An important point which affected this question of cage-gates had not been touched upon. He referred to landings half-way down a shaft, at which men were wound at irregular intervals. If automatic cage-gates were used, he supposed that they would open and shut as the cage passed these landings, even when the cage itself did not stop. He presumed that the appliances to work the automatic arrangement would be fixed at these landings, as the cage-gates would be required to open at the times when men desired to land; but it would be a most undesirable thing that the gates should open and close when they were not required.

Modern legislation, in the sense that it was seeking to cripple winding-hours, would naturally make colliery-owners wind men at a special winding-shaft. That being so, he thought it also followed that colliery-owners would need to wind men from landings in shafts more in the future than in the past; and, therefore, before any special gate was decided upon, he would ask colliery managers to consider carefully Mr. Thirkell's suggestion that the gates should be worked by hand, or that, if automatic gates were adopted, they should be so arranged that they would not open at those times when the cage was not intended to stop.

Mr. John Gerrard said that if they were to wait until the [redacted]

Mr. J. BOTTERILL (Leeds) wrote that it was generally accepted amongst factory inspectors and lift engineers that no door or gate which was not operated automatically was a sufficient guard. The greater number of accidents, such as falling down the well, being crushed by the cage, etc., had happened on lifts where the doors were opened and closed by hand.

It was this experience which had suggested to the writer the absolute necessity of making a pit-cage guard automatic in action. It was easy to fix a gate to be operated by hand, but such was no guard at all. Long experience had shown that men could not be depended upon to close the gate. Numerous instances could be quoted where even the lift attendant, whose duty it was to open and close the doors, had fallen a victim to his own carelessness.

With regard to Mr. Stokes's remarks about the gate closing before the cage began to travel, the writer thought that he must have overlooked the great speed at which the cage travelled. The gate invented by the writer's firm was closed before the deck to which it was fixed had disappeared from view, and could be made to close much more quickly by a simple alteration in the ratio of the sprocket-wheels. Inset or intermediate openings presented no special difficulty, and could be easily arranged so that the automatic motion need only be used when required.

Altogether, he could not see how, unless, perhaps, from the point of view of cost, a gate or guard operated by hand, could be of any advantage. On the contrary, it appeared to have many disadvantages, which were entirely done away with by automatic action. An automatic gate would always be sure in action, and in the prevention of accidents; and, as it required no attention, there was a great saving of time and trouble.

Mr. W. H. PICKERING (H.M. Inspector of Mines, Doncaster), in replying to the discussion, said that his object in writing the paper was to open discussion. He did not believe in any hard-and-fast rules being made, and he would like to point out that at their meetings they did not meet together as inspectors and managers, but as mining engineers. Referring to Mr. Hodges's objection, nobody would advocate automatic gates that would open at mid-insets, as it was suggested they might, when not required; whilst with regard to what Mr. Stokes had said, he pointed out that on most of the models before them the automatic apparatus did not begin to work until the cage was practically on the fallers.

A question had been raised by Mr. Laverick as to the stability of the gates, and he agreed that it was a most important matter that the gates should be sufficiently rigid to withstand the shock of a man falling against them. He agreed also that the gates must be made to fit the conditions; and, whilst appreciating the difficulties which attended the fitting of gates to some cages, the best use possible would have to be made of the conditions. As to the danger of cage-accidents, he agreed with what Mr. Gerrard had said. One man could say, perhaps, that nothing had ever happened at his colliery, and therefore that there was no danger; but in other parts of the district the same could not be said, as shown by the list of fatal accidents given in the paper.

Mr. G. J. Binns (President of The Midland Counties Institution of Engineers) then took the chair.

[redacted]

THE APPLICATION OF THE HYGROMETER IN COAL-MINES.

BY HENRY DAVIS.

One of the most interesting instruments in the equipment employed by the meteorologist in his daily observations is the hygrometer. It ascertains the amount of moisture in the air; and, besides its value to the meteorologist in often affording a better guide as to the probability of rain than the barometer itself, the hygrometer is of use in daily life as a guide to the proper regulation of the amount of moisture for places where workpeople are engaged, for the sick-room, and for the green-house.

The subject has been treated in an exhaustive manner by meteorologists, and ample instructions for the use and understanding of the hygrometer are contained in a work by James Glaisher.* This work, however, does not refer to the application of the hygrometer in coal-mines; and, as the percentage of moisture in the air has a very important bearing on the liability or non-liability to explosions in mines subject to coal-dust, and also on the health of the miners, the writer considers that a short paper explanatory of its usefulness, with some notes of instruction, may prove acceptable.

The subject of the measurement of humidity and the regulation of moisture in the air in coal-mines, and indeed in all mines, is so essential that it occurs to one as remarkable that the use of some ready means of measurement has not been adopted to any extent, and that the Government has not thought fit to make the use of the hygrometer obligatory. Since the year 1901 the Factory and Workshops Act has been, and still is, in force, and this lays down precise limits as to the grains of vapour per cubic foot of air allowed by the Act. (References to these limits will be made later on.) As it is more than possible that some rules may be issued for the guidance of mine-

* *Hygrometrical Tables*, by James Glaisher.

managers, these notes may be useful if considered only as being preliminary to the fuller treatment of the subject.

Much has been written as to the responsibility of coal-dust for the extension of some of the most disastrous explosions in coal-mines, and it would appear that spraying the mines with water is the best preventive remedy to control such extension; for, with plenty of water in the intake roads, it would seem to be impossible for coal-dust to be held in suspension in sufficient quantity to explode or to extend an explosion of fire-damp; but, so far, it does not appear that any scientific system as to the amount of watering has been adopted.

The over-watering of roadways in warm pits is undesirable, as the disease known as ankylostomiasis is encouraged by excessive moisture in a warm atmosphere. The ovum produced by the *ankylostoma duodenale* (miners' worm) flourishes in warmth and moisture. Dr. J. S. Haldane has stated that laboratory observations show that the larvæ are unable to reach the encysted state except at a temperature above 20° Cent. (68° Fahr.).

It is therefore undesirable on this account to overwater in pits where the temperature is 68° Fahr. and above, and care should be taken to avoid watering in the immediate vicinity of the miners' latrines. By overwatering is meant that the air cannot be more than saturated, which is indicated when the dry and the wet thermometers register the same temperature.

[redacted]

The hygrometer, therefore, should be employed; and the most simple instrument is known as the Mason hygrometer, which consists of two identical thermometers placed side by side. One has its bulb exposed to the surrounding air, giving the temperature of the air, while the other has muslin tied around the bulb, to which is attached an absorbent wick, and this wick is led into a vessel containing rain or distilled water, an arrangement by which the muslin is kept constantly wet. Care should be taken to see that the muslin is wet before observations are carried out. The evapora-

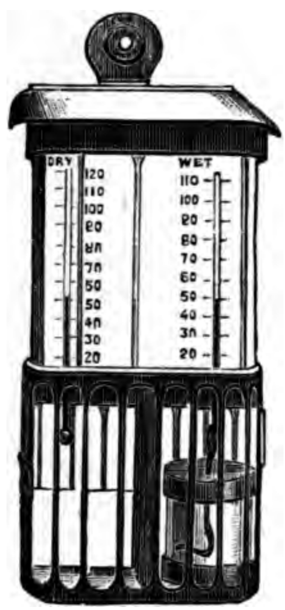

FIG. 1.—MASON HYGROMETER FOR FIXING AGAINST A WALL, ETC., FOR USE IN COAL-MINES, ETC.

FIG. 2.—MASON HYGROMETER: PORTABLE FORM FOR USE IN COAL-MINES.

tion from the muslin and consequent cooling of the bulb being in proportion to the dryness of the air. The difference of the readings of the two thermometers will be greatest when the air is driest, and these will read alike when the air is completely saturated with moisture.

The Mason hygrometer is usually constructed so as to be affixed to a wall in any convenient position. The scales are made of porcelain, so that they are easily cleaned and practically indestructible. Another form is constructed so that it can be carried from place to place. Fig. 1 shows a Mason hygrometer with its tubes well

apart. A web separates the dry and wet bulbs, so that the evaporation from the wet bulb will not reduce the temperature of the dry bulb; the case protects the scales and tubes from damage. This form is intended to remain in the intake roads for regular use.

The hygrometer as illustrated in fig. 2 is designed for conveyance, without fear of damage, in and about a coal-mine, and is sufficiently protected for carrying in a travelling-bag, a plug being provided to secure the water in the vessel. A handle enables it to be carried or to be hung on a nail, the bulbs are small and very sensitive, and always sufficiently exposed to take readings, a few minutes only being required to indicate the proper temperature. This may be hastened by gently swinging the instrument in the air.

The thermometers should be tested and certified at the National Physical Laboratory, Kew, and a certificate obtained shewing any necessary correction; they should be graduated on the stem, in order that they may be easily and accurately read by the aid of a miner's lamp. The lamp, however, should not be held too long or too near the bulbs, as the heat might affect the correct reading; preferably the lamp should be held on the return side.

To ascertain the amount of moisture in the air, that is, the degree of humidity, it is necessary to observe the temperature as shown by the dry and wet bulbs. The deductions from these [redacted]

thermometer read 68° Fahr., and it is desired to produce a complete saturation of moisture, the sprinkling should be continued until the wet thermometer also reads 68° Fahr.; and so on.

TABLE I.—HYGROMETRICAL READINGS.

Readings of Thermometers.		Humidity: Saturation, 100.	Amount of Vapour in a Cubic foot of air. Barometer reading, 29 inches.
Dry.	Wet.		
Degrees Fahr.	Degrees Fahr.	Per cent.	Grains.
65	65	100	6·8
65	62	83	5·6
65	59	68	4·6
68	68	100	7·5
68	62	68	5·2
68	59	56	4·2

In cotton-cloth and other factories where humidity of the atmosphere is artificially produced, the authorized limits are very narrow. It may be useful to give a short extract from the Government Regulations and state the limits of humidity as laid down in Table II.*

TABLE II.—DIFFERENCE BETWEEN DRY AND WET BULBS ALLOWED BY COTTON-CLOTH FACTORIES ACT.

Amount of Vapour per Cubic Foot of Air.	Dry-bulb Thermometer Readings.	Wet-bulb Thermometer Readings.	Humidity: Saturation, 100.
Grains.	Degrees Fahr.	Degrees Fahr.	Per cent.
5·10	60	58·0	88·0
5·20	61	59·0	88·0
5·40	62	60·0	88·0
5·60	63	61·0	88·0
5·80	64	62·0	88·0
6·00	65	63·0	88·0
6·20	66	64·0	88·0
6·40	67	65·0	88·0
6·60	68	66·0	88·0
6·90	69	67·0	88·0
7·10	70	68·0	88·0
7·10	71	68·5	85·5
7·10	72	69·0	84·0
7·40	73	70·0	84·0
7·40	74	70·5	81·5
7·65	75	71·5	81·5
7·70	76	72·0	79·0
8·00	77	73·0	79·0
8·00	78	73·5	77·0
8·25	79	74·5	77·5
8·55	80	75·5	77·5

* *Factory and Workshop Act*, 1901 [C.H.22], pages 49 to 95 and 96.

"Section 90 (chap. 22).—In every room, shed or workshop or part thereof in which the weaving of cotton-cloth is carried on (in this Act referred to as a "cotton-cloth factory"), the following provisions shall have effect:—

"(1) The amount of moisture in the atmosphere must not at any time be in excess of such amount as is represented by the number of grains of moisture per cubic foot of air shown in column 1 of the table in the fourth schedule to this Act, opposite to such figure in column 2 as represents the temperature existing in the cotton-cloth factory at that time."

"Provided that the temperature shall not at any time be raised by any artificial means whatsoever (except for gas used for lighting purposes only above 70°), except in so far as may be necessary in the process of giving humidity to the atmosphere."

"(2) The fact that one of the wet-bulb thermometers in the factory gives a higher reading than the figure shown in column 3 of the said table, opposite to such figure in column 2 as represents the temperature existing in the factory, shall be evidence that the amount of moisture in the atmosphere exceeds the limit prescribed by this section."

When the wet and dry bulbs show less difference than above, there is more humidity than the Act allows. Temperatures below 60 and above 80° Fahr. are excised in the above reference.

To obtain accuracy in ascertaining the degree of humidity, corrections have to be made with reference to the height of the barometer, but within ordinary ranges the corrections are minute, and may be neglected for the purpose in view.

The enforced employment of the hygrometer in coal-mines will add one more lesson for the colliery manager to learn to his already long list of subjects; but the writer maintains that considerable interest and pleasure will be attached to the study of the subject and its general application, and will well repay

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would produce the hygrometer and Mr. Stokes the results of his experiments, that would take them a step still further.

Mr. HENRY DAVIS said that one of H.M. Inspectors of Mines had informed him that he had recently made upwards of 5,000 hygrometrical observations in coal-mines, and that he was still carrying on an investigation of this nature for the Royal Commission on Mines. This led him to suppose that the subject might be brought prominently before the notice of colliery managers in the near future.

DISCUSSION OF MR. JONATHAN WROE'S "NOTES ON A RECENT UNDERGROUND FIRE AT WHARNCLIFFE SILKSTONE COLLIERIES, AND THE USE OF RESCUE-APPARATUS IN CONNECTION THEREWITH,"* AND OF SERGEANT ARTHUR T. WINBORN'S "NOTES ON RECENT EXPERIENCE IN THE PRACTICAL USE OF RESCUE-APPARATUS."†

Mr. A. H. STOKES (H.M. Inspector of Mines, Derby) thought that matters appeared now to be moving very fast in regard to this question. Would it not be advisable to hesitate a little and review the position? He saw from a statement in the newspapers that the Russian Minister of Trade had issued regulations that there must be so many trained men and apparatus always ready at "every colliery." According to this standard, Great Britain would require 7,000 appliances and 30,000 trained men. They had to look at the matter in a practical way, and not come to a hasty conclusion that many lives were going to be rescued. All honour was due to those men who had responded to the call and risked their lives by going down the pit at Hamstead. It was only what was expected, and what would always be expected, of miners whenever they were called upon. He had himself been in a tight corner more than once, but had never failed to get help from the colliers when duty called upon them to risk their lives in the cause of humanity.

There had been two recent occasions when a trained body of men had been called upon to use the apparatus for the rescue of life. In the Courrières disaster a life was lost, and again at

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 2. † *Ibid.*, page 7.

Hamstead another life was lost. In both cases the men did nobly; but, in view of such experiences, was it not right that men who risked their lives should ask mining engineers to do all that was possible for their safety? With reference to what occurred at Hamstead colliery, he had asked himself the question as he saw the men descend the mine: supposing some men were found alive, what could be done? They certainly could not be brought to the pit-bottom through nearly a mile of low roadway and noxious air. It was a question which he found himself unable to answer. Since the Hamstead case, a gentleman had, in view of similar disasters, suggested that cans of compressed food should be provided, and that sufficient for fifty persons should be kept in the mine at various parts of the workings; but if the same gentleman could suggest how tins of compressed fresh air could be stocked in the mine, it would be of far greater value.

Another point that struck him at Hamstead was that men were sent down into a noxious vapour. They had lights, but they were of diminished utility in such an atmosphere, and they had to grope their way into, what was to them, an unknown mine. They did not know where they were going, but had to explore their way. It seemed to him that when men were taking such risks it ought to be possible to trail a length of telephone wire after them. Half-a-mile of telephone wire would be very light, and the members of the exploring party would by its use be able to establish communication with the top or bottom of the pit. At Hamstead [redacted]

they be expected to travel long distances under such excitement and unusual conditions? These were questions which required their careful consideration as mining engineers. There were occasions when such appliances would be invaluable, such as in building stoppings, turning or restoring ventilation, exploring in advance of the air-current, and in other similar operations, and he hoped that there would soon be a corps of trained men available for all mines.

Mr. E. W. THIRKELL (Aldwarke) said that it must strike them all as practical men that it was extremely unfair to call upon one district to do work for another district which it ought to do for itself. There were at present only two rescue-stations, one at Normanton and the other at Tankersley; and the men at these stations were expected to respond to the call to go from one district to another. Men were always quite willing to risk their lives within reasonable limits; but he thought that they would all agree with him that it was not right that they should be expected to go into strange pits. The question asked by Mr. Stokes, as to how a man was to be got out if found alive, was an important one. Could the person wearing the apparatus carry a spare apparatus with him for the use of the imprisoned man while going through that part of the workings where the air was irrespirable?

The appliances were undoubtedly very useful for exploration purposes, re-arranging ventilation, etc., as at Wharncliffe Silkstone colliery; but he had not heard that life had actually and directly been saved by their use.

The suggestion that explorers should carry a telephone wire with them was interesting, but could they use it when wearing the apparatus? Even if they could not do so, however, the wire would serve as a guide in case they missed their way coming back; and it might also be used with advantage some distance from the shaft before the irrespirable air was met with.

Mr. A. LUCAS (Sheffield) said that at the last meeting Mr. Harry Rhodes had suggested that Mr. Wroe's paper would be more complete if the cause of the fire were stated; and, as the speaker was asked to make an inspection of the electrical plant as soon as the haulage house was cool enough to enter, a statement from him (Mr. Lucas) would, perhaps, not be out of place.

The electrical equipment of the haulage plant consisted of a compound-wound motor of 120 brake-horsepower, with a tramway-type controller and six resistance-boxes immersed in oil. Presumably in order to economize space, the resistance-boxes with their cable-connections from the controller were placed under the floor of the haulage house, a somewhat inaccessible place with little or no ventilation. The resistances were arranged for starting the motor slowly against a full load, but not for continuous-speed regulation, which was afterwards adopted. The motor never ran at full speed; in consequence, some of the resistances remained permanently in circuit, and became very hot. The cooling action of this oil in the boxes was interfered with by an accumulation of dirt.

In the speaker's opinion, the fire originated in the oil-boxes, where the oil became ignited either by the excessive heating of the resistances or by a spark from a loose cable or grid connection: for although the flash-point of the oil was about 365° Fahr., its temperature would be raised to a point dangerously near to that temperature by the hot resistances. The lesson to be learnt from this was that electrical apparatus which required inspection should be placed in a convenient place, to keep flame-tight boxes tightly covered, and, in the case of oil-cooled apparatus, to change the oil occasionally. If the resistances became too hot, the cause should be investigated, and their area where necessary increased sufficiently to reduce their temperature. In the case in

[redacted]

that the better equipment of telephones in collieries was important. The difficulty in cases of the kind was to know whether there was human life in the pit. A system of galvanized-iron telephone wires was inexpensive, and portable telephones could be carried by deputies so that they might communicate with each other.

The CHAIRMAN asked whether it was not a fact that telephone wires had been in existence, but had been destroyed by the fire. Mr. Davis had suggested that this mode of signalling should be fitted; and no doubt the communications would be all right, so long as they were not damaged by the fire.

Mr. D. RUSSELL (Thorncliffe) said that he did not think there was a breathing-instrument in use that would allow of the use of the telephone. The Dræger apparatus, for example, was fixed by a pneumatic joint round the head, and could not be taken off to communicate by speech with a telephone.

The further discussion of the paper was adjourned.

THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
APRIL 6TH, 1908.

MR. G. P. HYSLOP, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, which were confirmed and signed.

The following gentleman, having been previously nominated, was elected:—

STUDENT—
Mr. PERCY HOLT WAIN, Craig House, Congleton.

INFORMAL MEETINGS.

[redacted]

Council would award the prize, subject to the paper selected being of sufficient value to deserve it. It would not necessarily be published in the *Transactions*, but he hoped that it would be found worthy of appearing therein.

A GAS-TESTING APPARATUS.

Dr. J. S. HALDANE (Oxford) explained and demonstrated the use of a gas-testing apparatus, which Mr. John Cadman had employed in making mine-air analyses in connection with a series of experiments which he was carrying out for the Royal Commission on Mines. It was quite convenient to carry about underground, and had already been used considerably for testing air in coal and metalliferous mines. It would determine the proportion of carbon dioxide and fire-damp in the air, requiring only three or four minutes for each determination. It was designed for use underground, but usually it would be more convenient to take a 2-ounce bottle of air and make the analysis at leisure. The results were accurate to 0·01 per cent. In its original form, this apparatus was described in a work by the late Sir C. Le Neve Foster and himself.*

Dr. J. S. HALDANE then read the following paper on "Diving and Diving-apparatus, with Special Reference to Diving Work in Mines":—

* *The Investigation of Mine Air*, by Sir C. Le Neve Foster and Dr. J. S. Haldane, pages 115 to 120.

DIVING AND DIVING-APPARATUS, WITH SPECIAL REFERENCE TO DIVING WORK IN MINES.

By J. S. HALDANE, M.D., F.R.S.

In recent years, much attention has been given to apparatus for penetrating irrespirable air. Mine-workings or shafts are, however, not only liable to be temporarily filled with foul air, but also with water; and it is sometimes a matter of great importance to have the means of penetrating this water, either to save life, or, much more commonly, for other purposes. The subject of diving is therefore one of considerable interest to mining engineers.

In Westphalia, where so much has been done in connection with breath- [redacted]

sixteen times to carry out important work under water, chiefly in connection with accidental irruptions of water during the sinking of shafts. The majority of the students passing through the school receive instructions in practical diving, as well as in the use of breathing-apparatus for foul air.

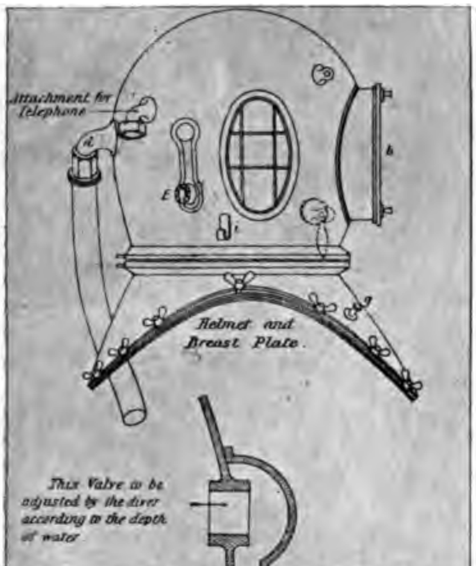
About two-and-a-half years ago, an Admiralty committee, of which the writer was the scientific member, was appointed to investigate diving as carried out in the Royal Navy. As a consequence of the report of this committee,* many improvements have been introduced, particularly for diving to great depths, and in the equipment and instruction of divers. In the course of the enquiry the whole subject was very thoroughly investigated from the physiological side.

FIG. 2.—DIVING DRESS, BACK VIEW, SHOWING ATTACHMENT OF AIR-PIPE AND LIFE-LINE, WITH TELEPHONIC CONNECTION; NEW PATTERN, WITH LEGS LACED UP TO PREVENT DIVER FROM BEING CAPSIZED AND ACCIDENTALLY BLOWN UP TO SURFACE, OR HUNG IN A HELPLESS POSITION.

The ordinary English diving-dress, devised in its original form by Mr. Siebe, consists of a copper helmet screwed to a metal corselet, the latter being clamped water-tight to a stout waterproof dress covering the whole body except the hands, which project through elastic cuffs (figs. 1 and 2). Air is supplied to the diver through a non-return valve at the back of the helmet, from a flexible pipe connected with an air-pump. The air escapes through an adjustable spring valve at the side of the helmet (fig. 3). The arrangement is thus such that the pressure of the air in the helmet is always equal to, or slightly greater than, the water-

* *Report to the Lords of the Admiralty on Deep-water Diving*, 1907 [C.N. 1549].

pressure at the outlet-valve. For every 34 feet of fresh water (33 feet of sea-water) the pressure increases by one atmosphere, or nearly 15 pounds per square inch. At a depth of 34 feet, the diver is therefore breathing air at an excess pressure of one atmosphere, or a total pressure of two atmospheres. It is absolutely necessary that he should breathe compressed air: otherwise his breathing would be instantly stopped, and blood would pour from his mouth and nose. In order to enable the diver to sink and stand firmly on the bottom, the dress is weighted with 40-pound leaden weights, back and front, and 16 pounds of lead on each boot—about 112 pounds of lead in all. Besides the air-pipe, the diver is usually connected with the surface by a so-called life-line, which commonly contains a telephone wire. He usually goes down by a rope attached to a [redacted]



the water at the valve-outlet, whereas the pressure on his chest and abdomen is greater by something like a foot of water. He is thus breathing against pressure, and if he has to breathe deeply, as during exertion, the effect becomes very serious. It would require only a few inches of additional adverse pressure to practically stop the breathing altogether. One of the first things that a diver has to learn is to avoid this adverse pressure by regulating the pressure of the spring on the outlet-valve, so that the breathing is always quite free. The spring on the valve at the same time regulates the amount of air in the dress, and therefore the buoyancy of the diver. A practised diver can thus slip easily, and without exertion, up or down the rope. The breathing is, of course, easiest when the dress is full of air down to the level of the abdomen; but, when this is so, the diver is in danger of being "blown up." It will also be readily understood that a horizontal, or nearly horizontal, position is the easiest one for a diver's breathing; and divers commonly work crawling on the ground. In this position it may easily happen that too much air gets into the dress. If this air is allowed to get into the legs of the dress, the diver is capsized and blown helplessly to the surface: or he may be caught by a rope or other obstruction, and hung up in a helpless position with his legs upwards, the excess of air being unable to escape at the valve since it is downwards. To avoid this risk, the arrangement for lacing up the legs, shown in fig. 2, is recommended. With the legs laced up, the head always comes uppermost if the diver tends to float upwards: hence the excess of air escapes by the valve.

In the Denayrouze apparatus, which is used in Continental navies, the air is pumped into a steel cylinder carried on the back of the diver. By means of a reducing-valve, the diver breathes through a tube direct from this cylinder, and expires through an outlet-tube. This arrangement is often referred to as an improvement on the English method just described. It is a beautiful piece of mechanism, but, in the writer's opinion, it is a quite useless encumbrance, giving rise to various inconveniences, and even dangers. This at least is his firm opinion, after trying it in Germany in the autumn of 1907. The definite advantages which it is often said to possess, in spite of its inconveniences, appear to be quite imaginary.

Apart from difficulties connected with hampered breathing and buoyancy, a diver on going under water may be greatly troubled by pain in his ears. This is due to the fact that the middle ear is an air-space communicating only with the back of the throat by the Eustachian tube, a narrow passage which is liable not to permit of the free entry of air from the nose. If this tube is blocked, and the atmospheric pressure increases, the pressure in the middle ear becomes less than outside. As a consequence, the membrane of the drum of the ear is bulged inwards, and the blood-vessels of the middle ear are gorged with blood, so that either the membrane may rupture or a blood-vessel may give way, causing bleeding. The pain is a warning symptom which must not be disregarded. The pressure in the ears is doubtless familiar to all miners, as it is felt to a slight extent in rapidly descending any deep shaft. By a peculiar swallowing motion the Eustachian tubes can easily be opened, unless they are blocked by catarrh. Divers soon learn the trick of opening their Eustachian tubes, and thus have no difficulty in descending rapidly; but in no case must pain in the ears be disregarded, as serious trouble may arise from bleeding or rupture of the drum of the ear. With a cold in the head, it may be quite impossible to dive.

It is commonly found that as the depth increases a diver's powers of work diminish, and he experiences more and more discomfort. At a depth of 70 or 100 feet, this is very marked; [redacted]

of carbonic acid. But if the air-supply to the diver is the same as that which amply suffices for him at a less depth, how can he suffer from excess of this gas? The answer is, that although the percentage of carbonic acid may be the same in the air breathed, the mass of carbonic acid in a given volume of air is not the same; and the effects of carbonic acid on a man depend, not on the percentage (unless the pressure remains constant) but on the mass of carbonic acid in a given volume of air—in other words, on the partial pressure exercised by the carbonic acid. Thus 3 per cent. of carbonic acid at atmospheric pressure exercises a pressure of 3 per cent. of one atmosphere, while at four atmospheres pressure (102 feet of water), it exercises a pressure of $(3 \times 4 =)$ 12 per cent. of an atmosphere; and its effects are the same as 12 per cent. of carbonic acid at atmospheric pressure. With 3 per cent. of carbonic acid the effects are comparatively small, but with 12 per cent. there is acute distress, and probable loss of consciousness very shortly.

Carbonic acid is so ubiquitous a gas in mining work that it may not be out of place to give a short account of some recent researches which the author has been engaged in on its physiological effects. Mr. Priestley and the writer have shown that at ordinary atmospheric pressure the breathing always regulates itself in such a way as to keep the percentage of carbonic acid in the air-cells (alveoli) of the lungs constant.* Each individual has his own exact percentage; but on an average there is about 5·6 per cent. of carbonic acid in the alveolar air of a man. The regulation is almost astoundingly exact for each person.

If air containing carbonic acid is breathed, the respirations become deeper, in such a way that the alveolar carbonic acid percentage still remains practically the same, if possible. If, for instance, there is 2 per cent. of carbonic acid in the air, the breathing will need to be about 50 per cent. deeper than before. This difference would not be noticed by the person, but is easily detected by measurement. If there is 5 per cent. of carbonic acid in the air, it requires much panting to keep the alveolar carbonic-acid percentage nearly constant: if there is 6 or 7 per cent., it is, of course, quite impossible to maintain a normal alveolar carbonic-acid percentage, and great distress is produced, as the blood becomes abnormally charged with carbonic acid, to which the body

* *Journal of Physiology*, 1905, vol. xxxii., page 225.

is exquisitely sensitive. If breathing of ordinary pure air is forced, so that the carbonic-acid percentage in the alveolar air is abnormally reduced, natural breathing is afterwards suspended for a short time, the condition known as "apnœa" being produced. It is carbonic acid, and carbonic acid alone, which regulates our breathing under normal conditions. The supposed ill effects of small percentages of carbonic acid in the inspired air are wholly imaginary, as a very slight increase in the depth of breathing at once compensates for the extra carbonic acid. Provided that this compensatory effort is practically inappreciable we may wholly disregard it. To any moderate variations in the oxygen percentage of the inspired or alveolar air there is no corresponding physiological response.

The writer and Mr. Priestley found that when the atmospheric pressure was varied it was the partial pressure, and not the percentage of carbonic acid, that remained constant in the alveolar air. The percentage varies inversely as the absolute atmospheric pressure, and was thus found to be lower at the bottom than at the top of a mine shaft, and lower in compressed air in exact inverse proportion to the increase of absolute pressure. To take extreme values, Dr. Boycott and the author have found 15 per cent. of carbonic acid in the alveolar air when the atmospheric pressure was diminished to nearly a third, some oxygen being, however, added to the air in order to prevent asphyxia from the low partial pressure of oxygen: on the other hand, Drs. Leonard [redacted]

From the practical side the matter was considerably complicated by the fact that the pumps used in the Navy were often old and extremely leaky under pressure. No test was in use for measuring the leakage past the pistons; and, when this was measured with the help of a gas-meter, a leakage of 70 per cent. was often found at the highest working pressures—occasionally 90 or even 100 per cent. Deep diving with such pumps was, of course, impossible; and even with thoroughly sound pumps it was necessary to couple up two double ones together before the necessary air-supply could be obtained for very deep dives where work had to be done on the bottom. It is essential in diving work to give the diver the amount of air that he requires at any given depth; and for this purpose the air-delivery of the pumps must also be known. The work of pumping, if done by hand, is extremely formidable at great depths.

In experimental dives made off the west coast of Scotland in 1906, Lieutenant Damant (now Inspector of Diving) and Mr. Catto, the two officers who were diving, reached a depth of 210 feet of sea-water, corresponding to an absolute pressure of 7·4 atmospheres, or 93½ pounds by gauge. This is the greatest definitely-recorded depth ever reached. They reached it within two minutes from the surface, and experienced no distress or discomfort. The samples which they took from the helmet-air showed that the partial pressure of carbonic acid had not risen beyond the calculated limit.

The author now comes to what is the chief danger in deep diving, or indeed in any work in compressed air at fairly high pressure. Since the early days of deep diving it has been well known that shortly after reaching the surface, divers in deep water are liable to sudden attacks of illness. Sometimes death results within a very short time; but paralysis, particularly of the legs and bladder, is much more common, so that the illness received the popular name of "divers' palsy." Often the paralysis passes off after a time more or less completely, but it may be permanent or lead to a lingering fatal illness. Among workers in caissons and tunnels at high air-pressure, similar cases of death or paralysis, or attacks of syncope, sometimes occur shortly after the men leave the air-lock in coming out. By far the commonest symptom in these men is, however, an attack of pain in one or other of the limbs, or occasionally elsewhere in the body. These pains are

known to the men as "bends" or "screws." They fortunately pass off soon, and usually occur within about an hour of leaving the compressed air. The whole group of symptoms has come to be known under the somewhat unfortunate name of "caisson disease."

The real explanation of all the varied symptoms of compressed-air illness, or "caisson disease," was furnished thirty years ago by the experiments and reasoning of the French physiologist, Paul Bert,* although up till recently the value of his work was not generally recognized, and various unfounded explanations of compressed-air illness are to be found in medical literature. The recent experiments of Dr. Leonard Hill and his assistants in this country,† and of von Schrötter and others abroad‡, have, however, removed all doubts, and added considerably to our knowledge of the subject.

When a gas is brought into contact with a liquid, the latter takes up the gas in simple solution, apart from any chemical combination, until a state of saturation is reached. The amount thus taken up depends upon the co-efficient of solubility of the gas in the liquid and the temperature of the liquid, and varies directly with the pressure of the gas, in accordance with what is known as "Dalton's law." The blood passing through the lungs is practically in contact with the air breathed, and therefore takes up, when a man or animal is in compressed air, an increased proportion of nitrogen and oxygen in simple solution,

[redacted]

in the lung air is kept constant by breathing, whatever the total atmospheric pressure may be.

The increased proportion of nitrogen taken up by the blood in compresed air passes to the various semi-liquid tissues, which gradually also become saturated, since nitrogen, unlike oxygen, does not disappear by entering into chemical combination. The whole body thus gradually becomes saturated with nitrogen at the pressure (79 per cent. of the total atmospheric pressure) which this gas exerts in the compressed air. That the blood does actually become saturated with nitrogen in this way was shown by Paul Bert, whose results have been confirmed and extended by subsequent observers.

If the excess of air-pressure is now rapidly removed, as occurs when a diver comes quickly to the surface, or when a worker in a caisson passes rapidly through the air-lock, it is clear that the blood and tissues will for a time be in a condition of supersaturation for the diminished pressure. In consequence of this, the nitrogen will tend to liberate itself within the body in the form of bubbles, just as carbonic acid is liberated in bubbles when the cork of a bottle of soda water is removed. When a liquid is saturated by contact with a gas, the pressure exerted by the gas in solution is the same as that of the gas in contact with it. The gas in solution will tend to liberate itself in the form of bubbles, if its pressure in the liquid exceeds the total external pressure. Thus, if the blood and tissues be saturated with air at a pressure of 4 atmospheres (that is, at 3 atmospheres above normal), the nitrogen in solution will tend to liberate itself in bubbles as soon as the external pressure falls below 79 per cent. of 4 atmospheres, that is, below 3·16 atmospheres. It does not follow, however, that any actual, or at any rate any rapid, formation of bubbles will occur, particularly in the case of an albuminous liquid like blood; and the lowest pressure by rapid decompression from which a fatal accident has occurred in a caisson worker is 23 pounds per square inch, or 2·6 atmospheres of absolute pressure, corresponding to 53 feet of sea-water. The occurrence of symptoms of any kind is very seldom observed with pressures of less than 2·3 atmospheres, or 19 pounds (43 feet of sea-water).

Paul Bert proved by numerous experiments on animals that sudden decompression from considerable pressures commonly causes death with symptoms of asphyxia, or else paralysis. The

higher the pressure, and the longer, within certain limits, the exposure to it, the more absolute does the certainty of death become. On *post-mortem* examination of the bodies of the animals he found the veins in various parts of the body full of bubbles, consisting almost entirely of nitrogen; and in the cases with symptoms of asphyxia the right side of the heart was full of froth, which had completely blocked the circulation.

The symptoms of paralysis were evidently due to partial or complete blocking of vessels supplying the spinal cord or brain; and in animals which had survived the paralytic attack for a few days, softening and the usual degenerative changes were found in the spinal cord at the places where the block had occurred.

Fig. 4 shows the bubbles in the blood [redacted]

and driving the blood corpuscles before them. In a moment or two the vessels became entirely occupied with columns of air-bubbles, and the circulation was at an end."* By means of rapid recompression, the gas was again driven into solution, and the circulation was re-established, the animal being uninjured.

The results of *post-mortem* examinations of the bodies of men who have died of compressed-air illness have entirely confirmed Paul Bert's conclusions. He pointed out, and partly proved by experiments on animals, that in order to avoid compressed-air illness slow decompression is necessary. He did not, however, show how slow the decompression had to be in order to secure safety. Nor has human experience since then solved this problem. What we do know is that when the excess of pressure has exceeded about 1½ atmospheres, or 22 pounds, the rates of decompression hitherto employed have proved more or less unsafe if the exposure has been long-continued; and that the higher the pressure the greater is the danger with a given period of exposure. At great depths, such as 30 fathoms, or 80 pounds pressure (5·4 atmospheres of excess pressure), an exposure of even 10 minutes has proved dangerous.

In view of the unsatisfactory state of knowledge as to what is a safe rate of decompression, it was evident at the outset of the Admiralty enquiry that a thorough investigation of the whole subject was needed; and meanwhile the means of carrying out the necessary experiments had been provided. The author had mentioned to Dr. Ludwig Mond, to whom scientific investigation in this country already owes so much, the need for a large experimental steel chamber for experiments on animals and men under varying air-pressures. He generously provided such a chamber for the Lister Institute of Preventive Medicine. The experiments in the chamber were undertaken by Dr. A. E. Boycott and Lieutenant Damant. During the last two years, several hundred experiments have been made in the chamber on goats and other animals, and on men, besides numerous diving experiments at sea; and the writer will endeavour to indicate briefly the theoretical considerations which were in view, and some of the main results.†

* *Journal of Hygiene*, vol. iii., page 436.

† For a full account of these experiments the writer would refer to a forthcoming paper in the *Journal of Hygiene*, vol. viii., by Dr. Boycott, Lieutenant Damant, and the writer.

First of all, it had to be considered in what way the process of saturation of the body with nitrogen occurs during exposure to compressed air, and the process of desaturation on return to normal pressure. From the existing evidence as to the mode of action of the lungs, it seems certain that, whatever the pressure of nitrogen in the air breathed may be, the arterialized blood leaving the lungs will be practically saturated to the same pressure. On exposure to compressed air, the unsaturated venous blood will become saturated in passing through the lungs; and on return to a lower air-pressure the supersaturated venous blood will become desaturated. On exposure to a high air-pressure, saturated arterial blood will be flowing from the lungs to all parts of the body. But these parts are just as capable of taking up an excess of dissolved nitrogen as the blood is. Hence during its passage through the body-tissues the blood will lose most of its nitrogen to the tissues; and the venous blood returning to the lungs will contain very little of the excess of nitrogen with which it started. In the lungs, however, it will be charged up again, though the amount which it gains there will, of course, not be quite so great as at the previous cycle of the circulation. At the next cycle the amount carried round will be still less; and so on. It will easily be seen, therefore, that the process of saturation of any part of the body with nitrogen must be capable of being graphically represented by a logarithmic curve. Supposing, for instance, that any part of the body becomes half saturated in half-an-hour, it will be three-quarters saturated in an hour,

[redacted]

tion—the fact, namely, that fat dissolves about six times as much nitrogen as blood does. It had been noticed that in animals which had died after rapid decompression the fat was often full of fine gas bubbles, and it was remembered that in the course of a quite different investigation, Dr. Vernon, of Oxford, had found that oils dissolve more nitrogen than water does. He has made some further accurate determinations for animal fats, with the result first mentioned.* The fat scattered throughout the body thus acts as a reservoir for nitrogen; and this probably about doubles the time needed for saturation or desaturation to occur.

To obtain a practical estimate of the time required for saturation of the body, Dr. Boycott and Lieutenant Damant made a number of experiments on goats, in order to see how far the frequency and severity of the symptoms increased with the duration of exposure. It was found that the symptoms increase with the duration of exposure up to about two hours, or a little more. From these and other data it was concluded that in goats some parts of the body giving rise to symptoms on decompression are not more than half-saturated in 45 minutes, and will desaturate with corresponding slowness. The rate of circulation in man is only about three-fifths as fast as in goats. Hence in man there will be some parts of the body which only half-saturate in 1¼ hours. Previous investigators have inferred that saturation and desaturation occur far more rapidly than this; but the above conclusions are in accord with practical experience in caisson work, where even after 3 hours' exposure to compressed air the cases of illness are less frequent than with longer exposures. This can be well understood if the rate of saturation is so slow.

The writer now comes to another point which has led to new and important conclusions. Practical experience of work in compressed air shows that even with very rapid decompression no symptoms of caisson disease occur with an absolute pressure of less than 2 atmospheres, and that symptoms are very rare and slight until the pressure rises beyond 2·3 atmospheres, or 19 pounds per square inch by gauge. This was found to be true

* *Proceedings of the Royal Society*, B, vol. lxxix., page 366. During the last few weeks Dr. Boycott and Lieutenant Damant have made a number of new experiments, not yet published. Their results show in the most conclusive manner that fatness very greatly increases the risk of death from compressed-air illness.

also for goats. Now if it is possible to decompress rapidly and with safety from 2 atmospheres, or a little more, to 1 atmosphere, it seemed likely that it would be possible to decompress with equal safety from 4 atmospheres to 2, or from 6 to 3, since the volume of gas tending to be liberated would be the same in each case. Experiment showed that this was the case, and that the danger of rapid decompression depends, not on the absolute difference between the initial and the final pressure, but on the proportion between the two pressures. If this proportion is only 2 or 2·3 to 1, the decompression is safe; if, on the other hand, the proportion is 3 or 4 to 1, the decompression is dangerous. To quote only one instance, a rapid drop from 6 to 2·6 atmospheres produced no symptoms at all, the fall of pressure being 3·4 atmospheres, and the relation of the higher to the lower pressure being 2·3 to 1. With the same animals decompression from 4·4 atmospheres to 1 produced disastrous effects, the fall of pressure being exactly the same as before, but the relation of the higher to the lower pressure being now 4·4 to 1. Two of the animals died, three had severe symptoms, three had "bends," and only two escaped without symptoms.

The method hitherto recommended for bringing men safely out of compressed air has been to decompress at a slow and uniform rate. But calculation on the principle already referred to shows that, however slow this uniform decompression may be, the difference in partial pressure between the nitrogen dissolved in the tissues and the external air-pressure will go on increasing

[redacted]

has elapsed to allow the maximum nitrogen pressure in any part of his body to become not more than twice the nitrogen pressure of the air at the lower stage. He is then brought on by further stages on the same principle until he reaches atmospheric pressure. For the difference between the stages, a pressure of 0·3 atmosphere was selected, corresponding to 10 feet of water. The diver's progress is, of course, controlled by signal from the surface according to the indications of the pressure-gauge on the pump. The proper stoppages, after stays at different depths, and for different periods of time, have been carefully calculated and put into the form of a table, which is now in use in the British Navy, and is quoted as an appendix.

For ordinary diving work the table limits the stay at the bottom in such a way that the diver can come up safely within half-an-hour. This is desirable for many reasons. After prolonged stays on the bottom at great depths the time required for safe decompression, even by the stage method, is too long for ordinary work.

ABSOLUTE PRESSURE, 6 ATMOSPHERES.

Series.	Exposure, in minutes.	Decompression, in minutes.	Number of Goats.	Stage Decompression.			Uniform Decompression.		
				Cases of "bends"	Severe symptoms.	Deaths.	Cases of "bends"	Severe symptoms	Deaths.
A	15	31	35	5	0	0	13	3	1
B	30	31	6	2	0	0	4	1	0
C	30	68	14	0	0	0	7	0	0
D	120	70	13	4	0	0	7	2	0
E	120	92	19	3	1	0	3	5	1
F	180	133	10	2	0	0	5	0	0
Totals.	—	—	97	16	1*	0	39	11†	2

* Paralysis of foot, lasting one hour.
† 3 cases of paraplegia, 4 of temporary paralysis, 2 of dyspnœa, and 2 of undefined illness.

The method of stage-decompression was very thoroughly tested on goats, and compared with the old method of uniform decompression. The result was to show beyond all question that the stage-decompression method is greatly superior, particularly for diving work. Even when the rate of decompression was much too fast by either method, stage-decompression proved considerably safer. The accompanying table shows a number of results obtained with the same animals and under the same conditions, except that the method of decompression was varied.

It should be remarked that in each series, except C, the rate of stage-decompression was less slow than what was calculated to be required for goats in order to prevent all symptoms, and considerably so in series B, D, and E. The occurrence of some symptoms was therefore expected. It will be seen, however, that deaths and severe symptoms were eliminated by the stage-decompression, whereas a number of cases occurred with uniform decompression in the same time, besides a much greater number of slight cases.

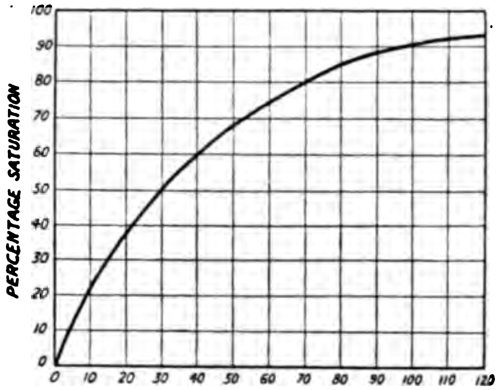
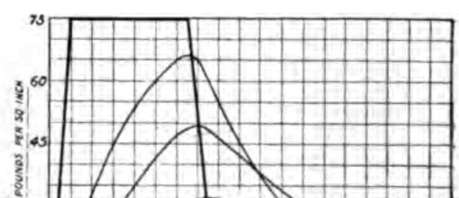


FIG. 5.—CURVE SHOWING APPROXIMATE RATE OF SATURATION OF PARTS OF THE BODY, WITH AN AVERAGE RATE OF CIRCULATION AND PERCENTAGE OF FAT.

With goats it was found necessary to provide for parts of the body taking as much as 45 minutes to become half-saturated or half-desatu-



[redacted]

others, with the time-limits and stage-decompression recommended in the new diving tables. No symptom of caisson disease, has, however, been observed, so that the new method appears to be practically successful. The old method was to go down and come up slowly, at a rate of about 5 feet per minute. Figs. 6 and 7 show the calculated degree of saturation of different parts of the body during a dive to 6 atmospheres pressure for 14 minutes with the old and the new method. It will be seen at once that the slow descent adds greatly to the danger, while during most of the uniform ascent many parts of the body are actually increasing in saturation, so that by the old method a diver runs a very serious risk of death or paralysis when he reaches the surface. By the

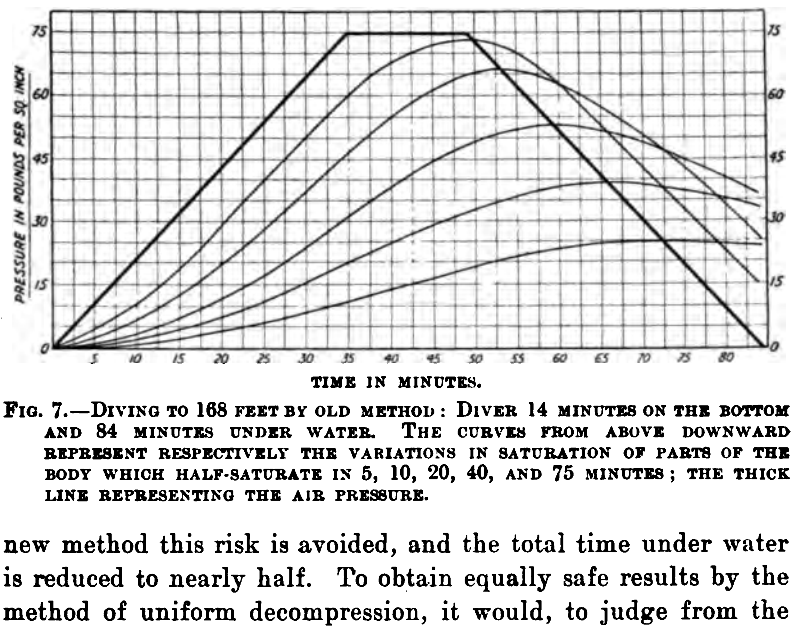


FIG. 7.—DIVING TO 168 FEET BY OLD METHOD: DIVER 14 MINUTES ON THE BOTTOM AND 84 MINUTES UNDER WATER. THE CURVES FROM ABOVE DOWNWARD REPRESENT RESPECTIVELY THE VARIATIONS IN SATURATION OF PARTS OF THE BODY WHICH HALF-SATURATE IN 5, 10, 20, 40, AND 75 MINUTES; THE THICK LINE REPRESENTING THE AIR PRESSURE.

new method this risk is avoided, and the total time under water is reduced to nearly half. To obtain equally safe results by the method of uniform decompression, it would, to judge from the experiments on goats, be necessary to extend the duration of decompression to several hours, the reason being that in the case of short exposures to high pressure not only is time wasted during the first half or two-thirds of the uniform decompression, but the saturation of most parts of the body continues to increase very seriously, so that at the end the decompression-rate is far too fast, unless the process is made very slow indeed. Uniform decompression thus seems to be quite impracticable for diving in deep water.

For most of the diving work likely to be needed in mines the ordinary diving-apparatus would probably be quite suitable. This apparatus is extremely efficient and safe, and inspires great confidence. In some cases, however, the length of pipe needed might cause much difficulty. If, for instance, it were required to go down a shaft under water, and then along a piece of submerged road, there would be great difficulty with the pipe. For this purpose a self-contained diving-apparatus, without any air-pipe, would be needed. As is well known, an apparatus of this kind was devised nearly thirty years ago by Mr. Fleuss, and used with signal success in saving the workings of the Severn Tunnel when they were accidentally flooded by an irruption of water.* In the Fleuss apparatus, which has been further improved by Mr. Davis, the diver breathes through a purifier containing caustic soda into an air-space contained in a waterproof jacket. Into this space oxygen is admitted from time to time from an oxygen-cylinder. The supply is not automatically regulated, however. In consequence, the oxygen-percentage is liable to get too low, so that the diver suddenly loses consciousness. A somewhat alarming accident of the kind occurred to Lieutenant Damant while he was testing this apparatus for the Admiralty committee. He became unconscious, and his breathing had stopped before he could be got out of the water and free of the apparatus. Fortunately, Staff-Surgeon Rees, the Secretary of the Diving Committee, was present, and quickly applied artificial respiration.

[redacted]

breathed. Pure oxygen in the breathing-bag of the Fleuss apparatus would thus be a danger if the depth exceeded about 17 feet of water with fairly long exposure.* The difficulty might be overcome by using a mixture of about 40 per cent. of oxygen and 60 per cent. of air. This would extend the range of safe depth to 70 feet, and any risk connected with the ascent would be lessened; but about 9 cubic feet per hour of this mixture would be needed, as compared with 4 cubic feet of oxygen. The extra weight of the steel cylinders would matter very little, however, as the diver must be weighted heavily to enable him to sink. Compressed air itself might even be used for filling the cylinders. About 70 cubic feet would suffice for a two hours' supply at any depth; whereas, if the air were pumped down into the ordinary diving-apparatus, about 720 cubic feet would be required for the same period at a depth of 100 feet, and 360 cubic feet at a depth a third as great.

Another very simple form of diving-apparatus, which is also made by Messrs. Siebe, Gorman & Company, Limited, has recently been devised by Commander Hall and Staff-Surgeon Rees with the special object of enabling men to escape from a submerged submarine. It is also a very efficient smoke-helmet. The general principle is that of the Pneumatogen life-saving apparatus. The diver breathes through an oxylith purifier into an air-space, and the action of the carbonic acid and the moisture of the breath liberate sufficient oxygen. To prevent blocking-up of the oxylith-purifier, a special arrangement of the material is adopted. For short immersions and moderate work, this apparatus works well. It is very light, and can be put on or taken off very quickly. It could probably be adapted without much difficulty for mining work. A diver could carry a spare apparatus with him for bringing out a man who had been cut off by water.

The problem of bringing out men cut off by water is one which has at various times occurred in mining experience. The only way of saving them may be to bring them out, but usually the problem is only that of keeping them alive until the water can be got under by pumping. For this purpose a diver could bring them food, and might probably be able to take in a flexible pipe

* With ordinary air at a pressure exceeding about 200 feet of water, the same source of trouble comes into consideration, and constitutes one of the difficulties in diving much beyond this depth.—J.S.H.

APPENDIX.

TABLE I.—STOPPAGES DURING THE ASCENT OF A DIVER AFTER ORDINARY LIMITS OF TIME FROM THE SURFACE.

Depth.		Pressure, in Pounds per square inch.	Time from Surface to beginning of Ascent.	Approximate Time to First Stop.	Stoppages in Minutes at different Depths.						Total Time for Ascent, in Minutes.
Feet.	Fathoms.				60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.	
0—36	0—6	0—16	No limit	...	...	...	...	...	...	...	0-1
36—42	6—7	16—18½	Over 3 hours	1	...	...	...	...	...	5	6
42—48	7—8	18½—21	Up to 1 hour	...	...	...	...	...	...	...	1½
			1—3 hours	1½	...	...	...	...	...	5	6½
			Over 3 hours	1½	...	...	...	...	...	10	11½
48—54	8—9	21—24	Up to ½ hour	...	...	...	...	...	...	...	2
			½—1½ hours	2	...	...	...	...	...	5	7
			1½—3 hours	2	...	...	...	...	...	10	12
			Over 3 hours	2	...	...	...	...	...	20	22
54—60	9—10	24—26½	Up to 20 mins.	...	...	...	...	...	...	...	2
			20—45 mins.	2	...	...	...	...	...	5	7
			¾—1½ hours	2	...	...	...	...	...	10	12
			1½—3 hours	2	...	...	...	...	5	15	22
			Over 3 hours	2	...	...	...	...	10	20	32
60—66	10—11	26½—29½	Up to ¼ hour	2	...	...	...	...	...	...	2
			¼—½ hour	2	...	...	...	...	...	5	7
			½—1 hour	2	...	...	...	...	3	10	15
			1—2 hours	2	...	...	...	...	5	15	22
			2—3 hours	2	...	...	...	...	10	20	32
66—72	11—12	29½—32	Up to ¼ hour	2	...	...	...	...	...	2	4
			¼—½ hour	2	...	...	...	...	3	5	10
			½—1 hour	2	...	...	...	...	5	12	19
			1—2 hours	2	...	...	...	...	10	20	32
72—78	12—13	32—34½	Up to 20 mins.	2	...	...	...	...	...	5	7
			20—45 mins.	2	...	...	...	...	5	10	17
			¾—1½ hours	2	...	...	...	...	10	20	32
78—84	13—14	34½—37	Up to 20 mins.	2	...	...	...	...	...	5	7
			20—45 mins.	2	...	...	...	...	5	15	22
			¾—1¼ hours	2	...	...	...	...	10	20	32
			Up to 10 mins.	2	...	...	...	...	...	3	5

[redacted]

APPENDIX.—*Continued.*

TABLE II.—STOPPAGES DURING THE ASCENT OF A DIVER AFTER DELAY BEYOND THE ORDINARY LIMITS OF TIME FROM THE SURFACE.

Depth. Feet.	Depth. Fathoms.	Pressure, in Pounds per square inch.	Time from Surface to beginning of Ascent.	Approximate Time to First Stop.	Stoppages in Minutes at different Depths. 80 ft.	70 ft.	60 ft.	50 ft.	40 ft.	30 ft.	20 ft.	10 ft.	Total Time for Ascent, in Minutes.
60—66	10–11	$26\frac{1}{2}$—$29\frac{1}{2}$	Over 3 hours ...	2	...	...	...	...	...	...	10	30	42
66—72	11—12	$29\frac{1}{2}$—32	2—3 hours ..	2	...	..	...	...	...	...	10	30	42
			Over 3 hours ..	2	..	...	...	...	...	...	20	30	52
72—78	12—13	32—$34\frac{1}{2}$	$1\frac{1}{2}$—$2\frac{1}{2}$ hours ...	2	...	...	...	...	...	...	20	25	47
			Over $2\frac{1}{2}$ hours...	2	...	...	...	...	...	...	30	30	62
78—84	13—14	$34\frac{1}{2}$—37	$1\frac{1}{4}$—2 hours ...	2	...	...	...	...	...	...	15	30	47
			2—3 hours ...	2	...	..	...	...	...	5	30	30	67
			Over 3 hours ...	2	...	...	...	...	...	10	30	35	77
84—90	14—15	37—40	1—$1\frac{1}{2}$ hours ...	2	...	..	..	...	...	5	15	25	47
			$1\frac{1}{2}$—$2\frac{1}{2}$ hours ...	2	...	...	...	...	...	5	30	35	72
			Over $2\frac{1}{2}$ hours ..	2	...	...	...	...	...	20	35	35	92
90—96	15—16	40—$42\frac{1}{2}$	1—$1\frac{1}{2}$ hours ...	2	...	...	...	..	...	5	15	30	52
			$1\frac{1}{2}$—$2\frac{1}{2}$ hours ...	2	...	...	...	...	...	10	30	35	77
			Over $2\frac{1}{2}$ hours .	2	...	...	...	...	...	30	35	35	102
96—108	16—18	$42\frac{1}{2}$—48	40—60 minutes	2	...	...	...	...	..	10	15	20	47
			1—2 hours ...	2	...	...	...	...	5	15	25	35	82
			Over 2 hours ...	2	...	...	...	..	15	30	35	40	122
108—120	18—20	48—$53\frac{1}{2}$	35—60 minutes	2	...	...	...	...	5	10	15	25	57
			1—2 hours ..	2	...	...	...	..	10	20	30	35	97
			Over 2 hours ...	2	...	...	...	...	30	35	35	40	142
120—132	20—22	$53\frac{1}{2}$—59	$\frac{1}{2}$—$\frac{3}{4}$ hour ...	3	...	...	...	...	5	10	15	20	53
			$\frac{3}{4}$—$1\frac{1}{2}$ hours ...	3	...	...	...	5	10	2)	30	30	98
			Over $1\frac{1}{2}$ hours...	3	...	...	...	15	30	35	40	40	163
132—144	22—24	59—$64\frac{1}{2}$	25—45 minutes	3	...	...	...	3	5	10	15	25	61
			$\frac{3}{4}$—$1\frac{1}{2}$ hours ..	3	...	...	...	10	10	20	30	35	108
			Over $1\frac{1}{2}$ hours...	3	...	...	...	30	30	35	40	40	178
144—156	24—26	$64\frac{1}{2}$—70	20—35 minutes	3	...	...	...	3	5	10	15	20	56
			35—60 minutes	3	..	...	...	7	10	15	30	30	95
			Over 1 hour ...	3	...	...	20	25	30	35	40	40	193
156—168	26—28	70—75	16—30 minutes	3	...	...	...	3	5	10	15	20	56
			$\frac{1}{2}$—1 hour ...	3	...	...	3	10	10	15	30	30	101
			Over 1 hour ...	3	...	5	25	25	30	35	40	40	203
168—182	28—30	75—$80\frac{1}{2}$	14—20 minutes	3	...	...	...	3	3	7	10	15	41
			20—30 minutes	3	...	...	2	2	3	10	15	25	60
			$\frac{1}{2}$—1 hour ..	3	...	3	3	7	10	20	30	35	111
			Over 1 hour ...	3	...	15	25	30	30	35	40	40	218
182—194	30—32	$80\frac{1}{2}$—86	13—20 minutes	3	...	...	...	3	3	7	15	15	46
			20—30 minutes	3	...	...	3	3	5	10	15	25	64
			$\frac{1}{2}$—1 hour ...	3	..	3	5	10	12	20	30	35	118
			Over 1 hour ...	3	5	20	25	30	30	35	40	40	228
194—206	32—34	86—$91\frac{1}{2}$	12—20 minutes	3	...	...	3	3	5	7	10	20	51
			20—30 minutes	3	...	3	3	3	5	10	20	20	67
			$\frac{1}{2}$—1 hour ...	3	3	3	5	10	15	20	3)	35	124
			Over 1 hour ...	3	15	20	25	30	30	35	40	40	238

to supply air, which could be breathed through masks if necessary.

It appears to the writer that, in connection with central rescue-stations, provision ought also to be made in at least two or three of these stations throughout the country for diving-

apparatus, and men trained in diving work underground. The nature of the apparatus and organization required at any such station would require very careful consideration by mining engineers, as well as the likelihood of diving-apparatus proving useful. Diving-apparatus and breathing-apparatus for foul air are so much akin that the men and organization for the one kind of work could readily be rendered available for the other. The best and most scientifically trained divers in the world are now those of the British Navy, so that there would be no difficulty in providing efficient practical instructors to make a start in the work.

The PRESIDENT (Mr. G. P. Hyslop) said that Dr. Haldane had given them a paper filled with most interesting facts, and had shown the members in clear and simple language the value of scientific research in the solution of the many problems which this subject involved. The suggestion contained at the end of the paper as to the provision of diving-apparatus and the training of men to use it, in connection with the various rescue-stations that were being established throughout this country, was one well worthy of serious consideration. The utility of such apparatus would undoubtedly vary in different districts, and, on the whole, would probably be greater in shaft-sinking through heavily-watered strata than in any other branch of mining, as appeared to have been the case in Westphalia. He did not [redacted]

of life-saving, which was of primary importance, there was, however, the question of the property in their charge, and, in connection with this latter point alone, the subject was well worthy of their fullest consideration. The statement made in the paper, as to oxygen at high pressure acting as a poison, was of particular interest when they recollected that the apparatus which would be used at the rescue-stations supplied nearly pure oxygen to the operators. He should like to ask Dr. Haldane whether any attempt had been made to adapt the liquid-air apparatus for diving purposes.

Mr. A. M. HENSHAW (Talke) said that Dr. Haldane's tribute to the divers of the British Navy was such as would be heard by everyone with great satisfaction. Dr. Haldane, in his modesty, however, had neglected to tell them of his own personal experiences; but, knowing what they did of his experiments on himself in regard to poisonous and irrespirable mine-gases, the members could imagine that that gentleman had followed up his researches into the possibilities of deep diving step by step by submitting his own person to some most exciting tests. He (Mr. Henshaw) noted that in the Blue Book on deep-water diving* reference was made to an experiment, in which Dr. Haldane had submitted himself, in the steel cylinder at the Lister Institute, to an oxygen pressure corresponding to about 40 fathoms of water, or what they would call high-pressure in a steam-boiler. Dr. Haldane had also, in conjunction with his son, aged thirteen years, taken part in the diving-experiments carried out on the west coast of Scotland. Before the appointment of the Diving Committee by the Lord Commissioners of the Admiralty, it appeared that diving to 130 feet was exceptional work, but it had now been made possible to do good work in safety at 210 feet, which depth might even yet be increased, although at this depth the body of the diver inside his dress was under an air-pressure slightly in excess of the outer water-pressure, or 93 pounds per square inch. It said much for the skill and care exercised in the experimental work that the experiments were completely successful throughout, the only mishap being when Mr. Catto got fouled in the coils

* *Report to the Lords of the Admiralty on Deep-water Diving*, 1907 [C.N. 1549], page 53.

of a rope at a depth of 180 feet. It had taken him 20 minutes to get clear, and those must have been very anxious minutes for Dr. Haldane and his party at the surface. It was noteworthy, however, how cool and sure they must all have been, for they saw how they applied the theory of slow-stage decompression in bringing Mr. Catto to the surface, occupying 1½ hours in doing so, and with such satisfactory results that Mr. Catto felt no ill-effects.

It was rather disconcerting to read how unscientific and unsatisfactory the work was before the committee's investigation. The former rule was slow descent at such a rate that it would occupy 41 minutes to go down 210 feet, though it was found that this was not only unnecessary but positively dangerous, because the diver, before commencing work, would be already saturated with nitrogen. It was now the rule to make the deepest descent in 2 or 3 minutes. Similarly, the ascent was formerly slow and uniform, or, indeed quicker near the surface; though, again, this was found to be not only wrong but dangerous. Now the practice was to re-ascend quickly to, say, half the pressure, and then slowly in stages, the more slowly near the surface.

The action of carbonic-acid gas and nitrogen was most interesting, and it struck him how similar the circulatory system of the human body was to the ventilating-circuit of the pit. The diver's arteries carried the oxygen and nitrogen to the extremities and capillaries and back by the veins; but the nitrogen accumulating in the vessels and tissues necessitated a gradual

[redacted]

must refer to a rescue which was effected last year in a mine in Western Australia, which won for the diver the Albert Medal of the second class. The mine was suddenly flooded, and all escaped except one man, who was working in a rise place, and was cut off by the rising water which filled his road of retreat. As the flood rose, the man was imprisoned, as in a diving-bell, and the air in the rise place being unable to escape, kept the water at a lower level than in the main shaft, at which place it rose to a height of 50 feet above his point of imprisonment. It was soon known that he was alive by his knocking signals on the rock, and, as there was little prospect of lowering the water for at least ten days, it was decided to reach him by the aid of divers. Two divers made the attempt. They had to descend an ore-shoot for 100 feet and pass along a level for a distance of 250 feet to the bottom of the rise place, one man staying at the bottom of the shoot to pass his comrade's air-pipe round the angle. There were many difficulties and repeated failures, but, after five descents, one of the divers got through to the imprisoned man, shook hands with him and left him an electric lamp and food. He had tried to picture the feelings of that man when he saw a glimmer of light in the water and watched the diver appear from below the surface. These visits were repeated daily until the water was lowered, and the man was rescued nine days after the flood.

Remembering the work that Dr. Haldane had done in connection with oxygen rescue-apparatus, it was interesting to hear what he said about the Fleuss-Siebe-Gorman self-contained oxygen diving-apparatus, but he gathered that it had not yet been adapted for work like mining, and could only be used for limited depths. In connection with the establishment of rescue-stations now going on in most of the coal-fields of the country, it seemed to him desirable that diving might be very properly included in one or two of the largest centres. It was noteworthy that this had been done in Germany, and that during the year 1907 they were called upon sixteen times for important mining work.

Dr. F. Shufflebotham (Newcastle-under-Lyme) said that Dr. Haldane had placed before them briefly the results of many years of investigation and research of a most intricate and difficult character, which involved a profound knowledge, not only of

chemical and physical principles, but also of mechanism; and these he had applied to the most difficult physiological problems which were known. The questions with which he had dealt would be difficult enough if they were carried out in a physiological laboratory, but how much more difficult were they when they were conducted upon the human subject? He (Dr. Shufflebotham) felt that not only the thanks of that meeting, but of the whole medical and mining communities, should be rendered to Dr. Haldane, for that gentleman had not only explained the theories of these various questions but, what was more, had shown that these theories could be put into practice; and, as a result of these investigations, many lives would be saved and much suffering mitigated, and valuable property would undoubtedly be preserved.

Dr. Haldane had explained to them the effect of pressure upon respiration from what he might call the chemical point of view; but, on reading through the paper, several points had occurred to him (Dr. Shufflebotham) which would involve other considerations. For instance, if the deepest expiration were made the pressure due to the elastic tension of the lung amounted to 6 millimetres of mercury, whilst during the deepest inspiration it reached 50 millimetres of mercury. He should like to ask what effect the conditions of pressure, such as Dr. Haldane had described, would have upon the elastic tension of the lung. Another point was with regard to the raising of the weight [redacted]

It struck him that the work of divers in mines was entirely different from that of divers in the deep sea, and Dr. Haldane incidentally referred to the short time during which divers could work even in the deep sea. It seemed, therefore, to him that the time during which a diver could do useful work in a mine would be even less than in the deep sea, because he (the diver) might not be familiar with the workings and ramifications of mines. This made it a matter of importance that in every mine, where divers might be required, there should be one or two men capable of undertaking the work of divers who knew their way about the mine. Dr. Haldane had spoken of the effect of pressure on the ears, and had referred to an easy way of removing the effect upon the ears. He (Dr. Shufflebotham) did not know whether this had been made perfectly clear, and he might therefore be permitted to say that the pressure in the Eustachian tube could be brought to its normal condition by the simple act of swallowing. If one swallowed the saliva, one could very often cause air to pass along the Eustachian tube to the middle ear, and thus equalize the pressure on each side of the tympanum.

Mr. E. B. Wain (Norton-in-the-Moors) said that he had pleasure in proposing a vote of thanks to Dr. Haldane. At a time like this, when they heard so much about rescue-brigades and life-saving apparatus, it was as well for them to be reminded that these matters were not to be entered upon lightly, and that artificial breathing and artificial methods of treating the human body almost required an artificial man for the purpose—decidedly not a fat man. Dr. Haldane had also, through his paper, given them something in the nature of a hint that the colliery manager of the future—who was already supposed to be an encyclopædia of knowledge—would have to add another "ology" to his curriculum, and that was physiology. He had great pleasure in proposing that the best thanks of the meeting be given to Dr. Haldane, and that the further discussion of his paper be adjourned.

Mr. John Cadman (H.M. Inspector of Mines, Newcastle-under-Lyme) seconded the vote of thanks. Like all Dr. Haldane's papers, the present one contained the results of

strenuous research. They were extremely obliged to Dr. Haldane for his very interesting and instructive paper.

The vote of thanks was carried unanimously.

Dr. J. S. Haldane (Oxford), in replying, said that he was extremely indebted to them for the interest which they had shown in the subject of his paper, and he need not say that it had been the greatest pleasure to him to come back to North Staffordshire once more and to meet so many old friends. It was really to North Staffordshire and North Staffordshire mine-gases that he owed a great deal of his knowledge of physiology. North Staffordshire mine-gases had suggested a number of new problems and new methods in physiology, including the investigation on the regulation of respiration, of which he gave them some account. He did not think that would have ever been undertaken but for his experience at Talk-o'-th'-Hill and in other North Staffordshire mines. It was in conjunction with Mr. W. N. Atkinson and Mr. Henshaw that he acquired most of his knowledge of mine air.

The President had asked him about the application of liquid air to diving-apparatus. So far as he knew, it had not been applied, and he was afraid that it would be difficult to apply it —for this reason, that liquid air was of very uncertain composition. When air was liquefied it was a mixture of nitrogen and oxygen in the proper proportion; but it evaporated, the nitrogen

[redacted]

apparatus. On the contrary, one felt the fresh air coming in, and there was no anxiety about breathing.

Mr. Henshaw had made a comparison between the air-circulation of the pit and the circulation of the blood in the body; and that was a comparison, which, if it appealed to mining men, appealed still more to physiologists. The points of similarity were very striking, and the methods of investigating what was going on in the mine, as regards air-supply and chemical changes, were extraordinarily similar in the two cases. He (Dr. Haldane) was accustomed to investigate the physiology of respiration and circulation, and he found that it came quite natural to investigate the respiration and circulation of a mine.

Dr. Shufflebotham had put one or two questions, which he would try to answer as briefly as possible. As to the elastic tension of the lungs and weight of the chest of a fat man, he really did not think that it would make any difference as to whether the man was under a pressure of 100 pounds to the square inch or nothing at all. When a person entered the compressed air in the steel-chamber, he did not feel anything; he breathed just as usual, and the rate of breathing was about the same. Theoretically it ought to be so, and actually it was. When it was stated that the rate of respiration had increased, the men had in nearly all cases been breathing air vitiated by carbonic acid. On the other hand, depression of the diaphragm was hindered to a large extent when one was in the diving-dress, because the pressure of the water gripped one round the waist. The sort of person who would be at home in a diving-dress would be a young lady who was accustomed to tight-lacing, for the young lady had to breathe mostly with the chest, and they had exactly the same conditions in diving. The diver's abdomen would not expand as freely as usual, so that his diaphragm did not do so much as the muscles of his chest, and in that way the action of the diaphragm was affected, much as Dr. Shufflebotham had suggested. As to the duration of work under water, in mining practice it would often be greater, and that was why he laid so much stress on the care required in bringing a diver up. In mining, cases would occur when the water was pretty deep, and where men had to work for several hours at a time, in which event the full precau-

tions would have to be observed. There was no limit to the time which a diver could work under water or under pressure; but, of course, as they could imagine, if he had been long under pressure, it would take a long time to bring him up, and that was an awkward matter in naval diving-work, because meanwhile a storm might come on, or the tide might become too strong for the diver, which would make it necessary to bring him up without much delay. Consequently, naval diving was fairly short in duration; but in a mine there was no reason why it should be so.

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MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
APRIL 14TH, 1908.

MR. JOHN ASHWORTH, PRESIDENT, IN THE CHAIR.

The following gentleman was elected, having been previously nominated:—

MEMBER—
Mr. SYDNEY ARTHUR CHAMBERS, Mining Engineer, 96, Gresham House, London, E.C.

Mr. CHARLES F. BOUCHIER read the following paper on "Enlarging an Upcast Furnace Shaft from 10 to 15½ feet in diameter, whilst Available for Winding Men and Coal."

ENLARGING AN UPCAST FURNACE SHAFT FROM 10 TO 15½ FEET IN DIAMETER, WHILST AVAILABLE FOR WINDING MEN AND COAL.

By CHARLES F. BOUCHIER.

Introduction.—The arrangement recently installed at the Strangeways Hall colliery, near Wigan, belonging to Messrs. Crompton & Shawcross, Limited, for the stripping and enlarging of an upcast shaft from a diameter of 10 to 15½ feet inside the brickwork, may be of interest to the members.

The shaft was already sunk to a total depth of 2,160 feet from the surface, being 10 feet in diameter down to 1,620 feet, and 14 feet in diameter for the remaining 540 feet.

The first thing to be done was to get a correct centre-line of the bottom length, and before commencing the work there were certain points that required careful consideration, namely:—

(1) There are four seams dependent on this shaft for ventilation; this is effected by means of a furnace placed in a mouthing 1,200 feet from the surface, which would not allow of the shaft being filled up and enlarged in that way.

[redacted]

winding coal, examining below the tube, and are available for drawing the men out from the mines below in case of emergency. There are three conducting-rods, 1½ inches in diameter, for the cage to travel up and down, and two ¾-inch ropes as conducting-rods for the hoppet.

The stripping operations were first commenced by working three shifts of 8 hours each; but when more coal was wanted, it was decided to wind coal for 8 hours, namely from 6 a.m. to 2 p.m., and to strip from 2 p.m. to 6 a.m. The men working in the mine from which coal is wound are lowered and raised by another shaft, and coal only wound during the 8 hours.

The first 600 feet in depth has been sunk for more than 50 years, and has twice collapsed and completely run in; on the first occasion about 45 feet from the surface, and on the second about 240 feet, which rendered the work of enlarging both difficult and dangerous, as the old curbs had given way and were very much out of the centre-line of the shaft below.

Commencing from the surface, the old shaft was excavated to 24 feet square, and pitchpine timbers 18 inches square put in every 7 feet in depth, with 7-inch by 3-inch planks behind these timbers. As the loose ashes and soft ground were taken out, the old brickwork was left standing to act as a fence and to keep the smoke from the men, being taken down as the sinking proceeded, about 7 feet each time, until solid ground was reached. Where the shaft had previously collapsed and had been filled in with loose ashes, the ground was very bad, and great care had to be taken to prevent it from again giving way for a depth of 45 feet to the metal, when a ring 15½ feet in diameter was laid, and the shaft bricked up solid to the timbers, which were taken out as the bricking up proceeded.

The ashes were wound in barrows, by means of a small steam-winch, which was very handy for getting round the sides, as also for letting bricks and mortar down for the bricking.

After the metal was reached and the sides became stronger, the shaft was excavated in a circular shape, making it 17 feet in outside diameter, in order to leave a finished inside diameter of 15½ feet. Where the metal had to be blown, precautions had to be taken to prevent it from falling down the shaft by slinging a tube of ½-inch plates 18 feet 6 inches long by 8 feet 3 inches in diameter, by means of two crabs on the surface attached by

1-inch ropes, with the large winding-rope as an additional safety. The tube was 8 feet 3 inches in diameter instead of 10 feet (the size of the shaft), in order to allow room for the hoppets to land and give more room for the men to move about, also to allow room for the shots to lift. In order to prevent metal from falling down the opening, a segment was bolted to the bottom of the tube. Double hand ratchet-drilling machines are used; they are first fixed in a horizontal position against the tube to drill holes about 18 inches deep, in which plugs are inserted for the machines, when the machines are fixed in a vertical position for drilling the shot-holes, which average 4 feet to 4 feet 6 inches in depth, according to the nature of the ground. Care has to be taken that these holes are not drilled below the bottom of the tube, and also to prevent the shots from simply blowing out at the bottom and not lifting the metal.

Nine and ten holes, which are all bench-shots, are drilled and charged, and fired by an electric cable and battery from the surface, which blow the metal against the tube, thus preventing it from falling down the pit. The débris is filled out and wound in the ordinary way. Skeleton rings and boards are placed every 4 feet apart to protect the side of the shaft, and are taken out as the brickwork lining is constructed. The tube is always not less than 4 feet below the bottom of the holes to be fired. When the sinking has proceeded to within this length of the bottom, the tube is again lowered, by means of the crabs and the winding-engine, to within 3 feet of the bench on which the sinkers are working.

[redacted]

that it is used. It is put together on two baulks placed in hangers, 18 inches long, from the bricking-ring and bolted by shot-bars. An opening is left in the centre (fig. 6, plate xiii.), 7 feet in diameter, with sheeting round it 4 feet high, to act as a fence and to allow the ventilation to pass through. It is raised by means of four 1-inch ropes attached to the main winding-rope as the bricking proceeds. When a length of bricking is completed, it is again lowered on to the timbers, there taken to pieces, and then sent up the pit. When coal was being wound, the scaffold was fastened to the skeleton-rings by means of a pulling-jack on each side, in order to liberate the winding-rope. The depth already completed and bricked is 681 feet, and has averaged 24 feet a week.

Ventilation for Sinkers.—During the stripping of the first 300 feet, the ventilation was taken down two ranges of 18-inch galvanized air-pipes, the fresh air going down the pipes and returning up the centre of the shaft. No more pipes have been put in, and the air now goes down the sides of the enlarged shaft and returns up the centre with the ventilation current from the other mines.

A vote of thanks was accorded to Mr. Bouchier for his paper.

Mr. Charles F. Bouchier (Wigan), replying to a question by Mr. George B. Harrison with reference to the broken ground where the collapse or " run in " of the shaft had previously taken place about 240 feet down, said that a certain amount of difficulty was experienced in getting through at that spot, which was overcome by putting down piles, and so keeping the soft ground back, and that the shaft had been sunk at various times, and was not absolutely perpendicular; the tube, therefore, could not be taken down the centre throughout.

Mr. Alfred J. Tonge (Bolton) asked Mr. Bouchier whether they were able to continue bricking all the time that they were winding coal, as he should think it would be necessary to uncouple the rope and leave the main cage at the bottom while the bricking-scaffold was raised, which would shorten their working hours. He considered the arrangement to have been on the whole very well thought out.

Mr. Bouchier replied that coal was not wound while the bricking was going on. As stated in the paper, coal was wound from 6 a.m. to 2 p.m., and the bricking took place from 2 p.m. to 6 a.m. Replying to Mr. James Ashworth, Mr. Bouchier said that the cage was detached at the surface, and that only about 10 minutes was required to change from coal-winding to sinking. No damage was done by the firing of shots. They were fired simultaneously.

DISCUSSION ON MR. JAMES ASHWORTH'S PAPER ON "AIR-PERCUSSION AND TIME IN COLLIERY EXPLOSIONS."*

Mr. W. N. Atkinson (H.M. Inspector of Mines, Bridgend) wrote that the object of Mr. Ashworth's paper appeared to be to prove that "percussion-effects" played an important part in colliery explosions. This theory had been advanced or discussed on several previous occasions, but the evidence and arguments put forward to support it failed to carry conviction. In the large number of explosions which he had investigated, he had found no indication to support the theory, nor any reasons for supposing such effects had occurred.

So far as the argument was based on the Courrières explosion, he thought that it was altogether erroneous. In the first place, it might be asked on what evidence or authority it was stated that "the floor of the [Lecœuvre] gallery was lifted,"† and "that the

[redacted]

With reference to paragraph 8, wherein it was stated that: "The indications of force from the Lecœuvre gallery were not directly towards No. 3 pit,"* the reason of this was explained on pages 467 and 468 of the paper on the "Courrières Explosion" by Mr. Henshaw and himself,† and on page 15 of the official report by Mr. Cunynghame and himself,‡ namely, that on the two more direct routes to No. 3 pit, the explosion was arrested for lack of coal-dust.

Paragraph 11 of Mr. Ashworth's paper stated that "The wet condition of the 1,070 feet (326 metres) north bowette did not restrain the flame of the explosion."§ The wet condition of this road was discussed on page 16 of the official report above referred to. As steam from the Cécile fire passed through it for many weeks after the explosion, the roof and sides were naturally wet or damp when examined; and the water-course by the side of the road being blocked through falls, and a pump being out of action, there was much more water on the floor after the explosion than before. The roof and sides of the bowette "were blackened with the usual coating of black dust found after explosions on dusty roads, and at one place coked dust was found." He had no doubt that the portion of this bowette traversed by the explosion had contained sufficient dry dust to account for its passage.

No. 3 pit was not "choked with débris" (paragraph 12, page 272). There was always a passage through the débris, first for the smoke of the explosion which invaded the bank at No. 3, as well as at No. 4 pit, and later for the air during 10 months when No. 3 pit was used as an upcast. What was meant by "heavy percussive effects" (paragraph 13, page 272)? As in all extensive explosions, damage was done on the roads traversed by the blast, timber was blown out, and falls of roof occurred in consequence. The bearing on the percussive theory of the position of the fires caused by the explosion was not apparent (paragraph 14, page 272).

With reference to the indications in the Lecœuvre gallery (which they had not been able to examine minutely), he did not think that it had been previously pointed out that all the frag-

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 271.

† *Ibid.*, 1906, vol. xxxii., page 439.

‡ *Report to H.M. Secretary of State for the Home Department on the Disaster which occurred at Courrières Mine, Pas de Calais, France*, on March 10th, 1906, by Messrs. H. Cunynghame and W. N. Atkinson, 1906 [3171].

§ *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 272.

ments of the fourth air-pipe, marked on the enlarged plan of the gallery (plate xxv., volume xxxii.), were found out-bye of the original position of the pipe, except some pieces (No. 142) under a fall just opposite the position of the pipe. Fragments of clothing and leather hats were also shown scattered from the face outward.

It might appear to Mr. Ashworth to be "practically certain" that his "proved facts" (some of which were not facts) demonstrated where the explosion began and all about it, but this paper was not likely to convert to his views those who made personal investigations of the explosion.

Mr. W. L. Hobbs (Pendleton) said that it was immaterial to the discussion of the theory of air-percussion whether the ignition, which Mr. Ashworth agreed with Messrs. Atkinson and Henshaw took place in the Lecœuvre heading, occurred from the cutting out of a missed shot, as Messrs. Atkinson and Henshaw thought, or whether it occurred from an ignition of explosive at the fourth air-pipe, as Mr. Ashworth, Mr. Stokes,* and Mr. Simcock‡ contended. It was a very interesting point, and a good deal could be said for both sides; but it was sufficient for that discussion to agree that somehow or other an ignition did take place at that point.

Mr. Ashworth's argument, however, that another, and as he (Mr. Hobbs) understood him to contend, the primary explosion, originated at the western end of the recovery-drift from the Marie [redacted]

there was fuel for it to feed upon. This seemed to have been the case, as the whole of these workings were traversed by the explosion, and all the men perished. There did not appear, therefore, to be any necessity to suppose that there was a separate explosion at the end of the recovery-drift. All the effects would take place without any such separate explosion if the fuel were coal-dust.

With regard to the statement in Section 11 of Mr. Ashworth's paper, namely, that "the wet condition of the 1,070 feet (326 metres) north bowette did not restrict the flame of the explosion,"* he would point out that Messrs. Atkinson and Henshaw had said† that from the evidence they obtained, the bowette was probably not wet before the explosion, except about the bottom of the staple pit from the Joséphine level, and that it was probable that there was an ample supply of dust available at that point, as the coal was tipped down the staple pit from the Joséphine seam just above. But in the south 1,070 feet (326 metres) bowette there was a wet zone 200 feet long, which stopped the explosion at that point; and it was from workings beyond this point that a party of 13 men escaped twenty days after the explosion.

It was also remarkable that in numerous cases the explosive effects disappeared when the dust contained a high percentage of incombustible matter, or was absent.‡ Several instances of this had been given by Messrs. Atkinson and Henshaw in their detailed description of the effects in the various districts. If Mr. Ashworth's theory as to air-percussion were correct, why should the explosive force stop at these places? Why should not the air-pressure restart the burning and coking effects after passing over these barren zones? The workings were most complicated: branch roads and staple pits were abundant. The percussive effect of the air would have passed many junctions, including the area about the bottom of No. 3 shaft, where the roads must have been of large size, before reaching these barren spaces. If it had persisted so far, why should not the effect have been the same all over the workings until it arrived at the open shafts? Messrs. Atkinson and Henshaw had given many instances where the burning effects ended with the end of inflammable dust. Why should they have ended just at those points if the effects were caused by heavy air-pressure?

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 272.

† *Ibid.*, 1906, vol. xxxii., page 467. ‡ *Ibid.*, page 455.

With regard to accidents caused by air-blasts, a paper had been read on the subject by Mr. Thomas Adamson,* and an interesting discussion had ensued, to which Mr. Ashworth made an important contribution. Details were there given of a number of cases in which damage was done and men killed at a considerable distance from the fall. In all the instances, however, the cause was a huge fall of a considerable thickness of a strong roof, over extensive areas of goaf measuring as much as 100,000 and 200,000 square feet. Naturally, when the large quantity of air displaced by this huge fall was forced along the contracted cross-section of the roads, very high pressure would be developed, and the resulting damage was quite understandable. But they had heard of no such huge falls occurring at Courrières. On the contrary, it was evident from the system of timbering enforced at these collieries that the roofs were not strong enough to stand over a large area, even if no packing had been done. It was likewise impossible that a fall in the recovery-drift, which, being a cross-measure road, would not be of large cross-section, could develop an air-pressure anything like sufficient to cause burning and coking effects in roads with a cross-section at least as large as its own.

Again, Mr. Ashworth, in his contribution to the discussion of Mr. Adamson's paper, in discussing the Mount Kembla disaster,† had stated that the large fall of roof was admitted by all the witnesses. He proceeded to state that the effects were felt only in the straight main haulage way, and not in branch roads which [redacted]

ing was reached after the explosion, it had been unventilated for nearly three months, yet no trace of fire-damp could be detected.* Subsequently, bore-holes were put into the coal and also into the adjacent fault, but no fire-damp was found.† Yet if it was dust that carried forward the explosion, it was dust at the working-face. And it had so far been understood that it was the old dust back on the main roads, which had been deposited by the ventilating current, and which had absorbed additional oxygen, that was the chief danger.

The point to which he (Mr. Hobbs) wished to draw attention was illustrated in the "Experiments illustrative of the Inflammability of Mixtures of Coal-dust and Air,"‡ by Dr. Bedson and Mr. Widdas. These experiments pointed to a theory that dust, on standing in contact with air, instead of becoming more inflammable, lost some of its inflammability. A specimen of freshly ground coal-dust ignited at a temperature of about 1,335° Fahr. After standing only 17 days in contact with air, it required about 1,490° Fahr., showing an increase of 155° Fahr. This raised the point as to whether coal-dust at the working face, where machines were working, especially punching-machines, might not be in some cases as dangerous as dust farther out on the main roads, or even more so where such main-road dust was largely diluted with shaly matter.

Mr. W. Ollerenshaw (Denton) said that he was of the same opinion as Mr. James Ashworth, namely, that there had been in a large number of colliery explosions of the past a variety of effects that could not be satisfactorily explained, unless the theory of air-percussion was accepted. The indications of the direction of the force of the explosion in the Lecœuvre heading at Courrières could scarcely be explained by any other method of reasoning than that advocated by Mr. Ashworth, and this also applied to a large number of the great explosions of recent times.

Having had some experience of the effects of air-compression in the mine, he could understand that most of the effects described in Mr. Ashworth's paper might, with truth, be attributed to this cause. Some years ago, whilst working at the coal-face at the Dukinfield collieries, engaged in working out a pillar of coal on the lower side of the main level, for the purpose of lodge-room for

* *Trans. Inst. M. E.*, 1906, vol. xxxii., page 473.

† *Ibid.*, page 474. ‡ *Ibid.*, 1907, vol. xxxiv., page 91.

water, a space measuring something like 600 by 60 feet was left behind; and, owing to the lack of support, the roof, which was of a very hard and compact rock, commenced to "weight," this going on for a considerable time, until a break took place. Hearing this break, he had warned his workmate, and they had both begun to run along the lower side of the pillar. They had got about 150 feet along this level, when the roof in the waste previously referred to fell with a tremendous crash. The compression of the air was so great as to blow them forward for a considerable distance. The workmen in other parts of the mine felt the concussion, and came to the conclusion that there had been an explosion in the pit. He (Mr. Ollerenshaw) believed that if the air compressed by the fall had not had several roads through which it could escape, and if they had been running along a level cut in the solid coal, they would have been thrown either against the face or sides of the level, and their lamps broken or damaged. The natural inference would have been that the accident was due to an explosion of gas liberated by the fall and ignited by the lamps, although as a matter of fact no gas was present, either before or after the fall took place. It was owing to this experience and to the unsatisfactory results of some of the investigations into the causes of colliery explosions in the past that he welcomed the paper of Mr. James Ashworth, and was pleased that the matter had been brought before the members, as probably same satisfactory explanations might be elicited.

[redacted]

in various panels and districts of the two mines, and that these simultaneous centres of explosion phenomena were probably due to the ignition and explosion of gunpowder in canisters. So effective were these "simultaneous" explosions in carrying the disaster, first throughout No. 8 mine, and then throughout No. 6 mine, that the fact of both mines being ventilated by separate fans, and the workings laid out with a view to the very highest point of safety, did not enable one single man to escape alive. Both mines were worked with open lights.

One point not noticed by Mr. W. N. Atkinson, but prominently referred to in the paper, namely, "time," had received most valuable support from the demonstration at Monongah. Thus the difference of time between the explosion making itself obvious on the surface at No. 8 mine and then at No. 6 mine was five seconds, and this accounted for a speed of about 3,000 feet per second. In addition to this interesting fact, although there was tremendous force demonstrated at the mouth of No. 8 mine, there was practically none at the mouth of No. 6 entry.* Inside this entry, about 200 feet, three men were killed in a tool shanty without a burn or bodily injury, and the cause of death was undoubtedly concussion of the brain from "percussive" effects on the air.

In all probability, no such complete disaster had previously occurred in any part of the world, and its demonstrations of force and effect had entirely upset several theories, such as the possibility of restricting the extension of an explosion in a mine or mines when divided into separate districts, and these districts again subdivided into separate panels. Then, as to Courrières, if the time when the explosion effects appeared at the top of No. 3 pit had been taken, and compared with similar indications at the top of Nos. 4 to 11 pits, most valuable information would have been forthcoming.

The evidence of the upheaval of the floor in the Lecœuvre gallery, at the point where the air-pipe was smashed into fragments (fig. 1, plate xiv.), was a matter of fact, and not of theory, and would be found in the reports, and also by reference to the report of Mr. G. Léon, Chief Inspector of Mines. Mr. Atkinson had said that the floor "was not" disturbed, without giving his authority for this denial of a fact which was demonstrated on

* There were similar demonstrations at the entry of No. 2 mine at the Fernie explosion; see *Trans. Inst. M. E.*, 1902, vol xxiv., page 450.—J.A.

the official plan. Before Mr. Atkinson again insisted that an air-pipe made of sheet-iron or steel could be smashed into, say, 89 pieces by a so-called blown-out shot, he (Mr. Ashworth) would suggest that the Home Office should be asked to make experiments to prove its possibility, as at present its positive impossibility was proved by the fact that the coal tram which was being loaded by Regis was in the direct line of fire, and instead of being reduced to matchwood, was comparatively little damaged.

With regard to paragraph 14 of his paper, the bearing of this fact was that there was no proof of the flame of the explosion reaching the points named, and that these fires were therefore caused by the effects of percussion on mixtures of fire-damp and air or some other easily ignitable substances.

Referring to the subject of facts or no facts, he (Mr. Ashworth) could not reply to these where the "no facts" were not indicated, but he might add that the official plan of the Lecœuvre gallery showed that the pieces of the dismembered air-pipe were found under a fall of roof from just above where the pipe had originally been placed, and therefore it was clearly demonstrated that the pieces of pipe were in position before the roof fell. Mr. Atkinson possibly had not had the opportunity of noticing that the lower side rail of the waggonway was lifted considerably above (11 inches) the higher side rail (fig. 1, plate xiv.)

Referring to the plans of the Monongah mine, Mr. Ashworth said that the experts called in after the explosion, though not agreeing as to the point of origin, were unanimous in their opinion [redacted]

ference had been made to "goaf-blasts," and in these there was a remarkable instance of the effects of air-percussion, namely, in the little injury sustained by the men who were near to the falls, whereas those farther away were killed. The Mount Kembla disaster differed from the Monongah disaster in several ways: there was no fire-damp, no blown-out shot, no means of ignition so far as was known, nothing but an exceedingly heavy fall of roof; the effects of that fall were almost entirely confined to one haulage road inbye and outbye, and the only explosion which took place was on the surface, where people were burned and materials set on fire, and not in the pit. The effects inside the mine were caused entirely by air-pressure and the mechanical force of the blast.

Replying to Mr. W. L. Hobbs as to Dr. Bedson's tests, Mr. Ashworth said that he did not consider old dust half as dangerous as new dust. New dust, as ascertained by Dr. Bedson in his experiments, commenced to give off gas immediately after separation from the solid coal. Under such conditions, he (Mr. Ashworth) considered that each particle of coal-dust floated along in its own balloon of gas, and, therefore, that it ought to be estimated as a gas and not as a solid, and that it was the greatest danger in a coal-mine where explosives were used.*

Mr. Hobbs did not seem to think that it was necessary to suppose that there was more than one explosion at Courrières. Therefore, as there was an undoubted explosion in the Lecœuvre gallery, which he (Mr. Ashworth) had shown conclusively could not have originated from a blown-out shot, it became necessary to find a possible cause, and he had found that there were two, and probably more, simultaneous explosions which could not now be traced for lack of precise information; and he had considered the place where the recovery-drift crossed the Marie level in No. 3 pit as the centre of the demonstrated force (see fig. 8, plate xxii., vol. xxxii.). As to this point, the indications of force radiated away from it in every direction; thus the door which directed the intake air into the Marie deep workings was completely swept away, and no trace of it was found. The Marie was the only mine in No. 3 pit lighted by safety-lamps, and therefore if this door were left open for a time, gas might have accumulated

* See "An Ignition of Coal-dust at Middleton Colliery," by Mr. John Neal, *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 221.

and have been carried on to one of the open lights in the stone drift, and ignited when the door was again closed. The ignition of explosives in many parts of the pits involved in the disaster was quite possible, but no investigation appeared to have been made to ascertain what became of the stocks of explosives. He believed that ignitions of explosives took place in other parts of the workings, and, as at Monongah, were main factors in extending the area affected by the disaster. Excess of dust was a more certain condition to bring any explosion to a termination than dirty dust; and certainly where fire-damp was a factor in an explosion, fine dirty dust was as dangerous as coal-dust.

He (Mr. Ashworth) did not dispute that the combustion or explosion of dust took place at Courrières, but the conclusion to which he had come was, that the explosion was extended by air-percussion: that was to say, if air-percussion had not been a factor, the explosion would have been confined to a smaller area, that the upheaval of the floor of about 11 inches (fig. 1, plate xiv.), the non-destruction of the tram in the end of the Lecœuvre gallery (fig. 2, plate xiv.), the indications at the top and bottom of the Joséphine drop pit, and the reported indications of force in the recoupage, all showed most distinctly that the effects from the originating cause of the explosion were not entirely due to the ignition of coal-dust, and that air-percussion was a principal factor, in which opinion he was pleased to find he had at least one supporter in Mr. Ollerenshaw.

On many occasions the possible pressure exerted by colliery [redacted]

DISCUSSION OF MR. GEORGE H. WINSTANLEY'S PAPER ON "ACCIDENTS IN WINDING, WITH SPECIAL REFERENCE TO ROPES, SAFETY-CAGES, AND CONTROLLING DEVICES FOR COLLIERY WINDING-ENGINES."*

Mr. G. H. Winstanley, in replying to Mr. Henry Hall, said that he was sorry if any observations in his paper could be construed into an implication derogatory to the colliery manager. Nothing was farther from his intention. As the President, for the time being, of the Lancashire Branch of the National Association of Colliery Managers, he desired to make this quite clear, and to remark that no one was more ready at all times than himself to uphold and safeguard the reputation of the colliery manager.

With regard to cheap ropes, he thought that Mr. Hall would be willing to admit, as Mr. Ollerenshaw had indicated, that cheap ropes were manufactured, and sold, and that therefore there must be both purchasers and users. Whenever a purchaser had the choice of two similar articles, one of which was offered at a lower price than the other, there was a right and proper tendency at least to consider why the cheaper one should not be selected. If it proved to be undoubtedly inferior, then, of course, no sensible person would hesitate. But in the case of steel-wire ropes, it was not always possible to make a selection so easily. Two ropes might be offered, both of the same size and weight, both made from wire of the same size, both professing to possess the same degree of strength, and apparently, on a test, giving proof of this equality. How then was the purchaser to decide? Be he colliery manager or proprietor, he would most naturally feel disposed to purchase the cheaper rope, which apparently was as good as the more expensive one. The object of this portion of his paper had been to show that it was possible to produce two ropes, one much cheaper (in first cost) than the other, and yet each should be capable of giving the same tests of tensile strength, torsion, and bending. Even the analysis of the two samples of steel might be the same, and still in use the cheaper rope would have the shorter life and would accomplish less.

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 134; and *Trans. M. G. M. S.*, 1908, vol. xxx., page 240.

He had endeavoured to show how the cost of manufacture could be cheapened at the expense of the life of the rope. The valuable invention of Messrs. Vaughan and Epton had made it possible to apply a more practical and more satisfactory test, one which would, in a manner of speaking, crowd the working life of the rope into a few hours. By this means one would be enabled to determine which of two or more wires was of the better quality, and to ascertain relatively how much more work one rope would do than another under the same conditions and treatment.

He feared that Mr. Livesey had rather lost sight of this particular point in the paper, perhaps the most important point in that part of the paper relating to ropes. He thought that the "fatigue" test carried out by such an appliance as that invented by Messrs. Vaughan and Epton went a long way towards meeting Mr. Livesey's, as well as every other rope-user's, requirements.

In further reply to Mr. Leonard R. Fletcher, he would like to say, on the subject of the "factor of safety," that he foresaw this difficulty in the near future when very deep shafts became more common. The task of surmounting this difficulty, however, would, he thought, be undertaken very largely by the wire manufacturer and the steel expert. He had already raised the question with steel experts and wire manufacturers, and he was assured that when the time came, that was, when the demand arose, there would be found a means of meeting it without reducing more than to a very slight extent the present factor of safety. He was [redacted]

passing. He would like to see these laws "boiled down" into a more compact and convenient, but not necessarily less comprehensive or less effective, form.

He was scarcely prepared to take up the subject introduced by Mr. Eckmann; it was rather outside the scope of his paper. He was quite prepared to admit that electric winding arrangements possessed many advantages; but his paper dealt rather with arrangements as they existed to-day, and he had little doubt that the steam winding-engine would, for many years to come, figure very largely in the equipment of British collieries.

Mr. Rushton's observations, with regard to the use of keps, would, he believed, be supported by many colliery managers. He was in favour of their use whilst raising and lowering men.

Mr. Joseph Dickinson (Pendleton) said that Mr. Winstanley's paper was so nearly exhaustive as almost to preclude addition or comment; but a few remarks might be allowed on some breakages of ropes, and on safety-catches for cages.

As to rope breakage, whilst cordially approving of holding managers responsible for everything within the scope of their duties, it seemed perhaps too exacting to include the breakage of every winding-rope. Strain resulting in breakage might occur in various ways with heavy loads being brought into rapid motion, even with all the care so generally bestowed by the winders. Breakage had also occurred without sufficient sign of failure, from either bad material to begin with, or decay from improper storage, over which the manager had no control, and for which it would be unfair to hold him responsible.

As to safety-catches on winding-cages, they had saved life and also much damage to property; therefore as a safeguard in the event of breakage they might be looked upon otherwise than as a beginning at the wrong end. At any rate, some of the circumstances associated with their use might be mentioned.

Premising that they certainly added weight to the load, which was a disadvantage, and that they also required some care to keep in order, substantial guides were required to support the arrested load, which generally helped to keep all steady. They also afforded the comforting assurance that, even if they did not on every occasion secure immunity, they did at times avert danger. Like safety-boats for escape from shipwreck, they did not always succeed; but the sailors who were most exposed were said to like

them. As an occasional assurance in winding, catches should not therefore be hastily parted with.

Formerly, single link-chains were used as guides in shafts, and also iron rods; then came wooden guides suitable for all depths, and with them the opportunity for the safety-catches; whilst now wire ropes, with fly ropes between to prevent collision of cages at meetings, were becoming common, but very much less suited for the catches.

The first automatic safety-cage known in this country was that devised by Mr. Edward N. Fourdrinier, as described in the Report from the 1849 Committee of the House of Lords. It was received with mixed hope and doubt, and, not proving satisfactory, disappeared. Others followed, some of which succeeded in running successfully at all speeds.

Confidence in them became such that at one time a proposal was made for their compulsory use, together with the use of the disconnecting apparatus with safety-hook as a protection against overwinding. Consequently, enquiry was made, from which it appeared that in 1879 in the Manchester and Ireland district, 189 safety-catches were in use, and 115 disconnecting appliances. Of the catches, 184 were the Owen, 4 the Broadbent, and 1 the Walker catch, a drawing of the Owen catch appearing in the official report for that year.* Of the disconnecting appliances, 86 were the Ormerod, 16 the Bryham, 9 the Walker, 2 the invention of another Mr. Walker, and 2 the Broadbent.

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was done that was possible, occasional breakages must take place. Mr. Winstanley said that he had expressed a rather extreme view, in order to elicit discussion. He (Mr. Harrison) was quite sure colliery managers were not lacking in courage in this matter, but they wished to be assured that what was intended to prevent accidents would not be likely to cause them. He had never known an accident through safety-appliances coming into operation. One case had been recorded of an accident which caused damage to property, but no loss of life; but he knew personally several cases where they had prevented damage from being done. It had been proved that even the old form of Owen catch would act and do good work when it was in proper order. It was no great length of time since, in the Manchester district, a cage was saved from going to the bottom. He knew also of several other cases where the safety-catch had acted, and also of cases where ropes had broken where it had not acted; but in all the cases with which he was personally acquainted, only that had happened which would have happened whether they had had a safety-hook or not; so that all his experience indicated that it had been a great advantage, and a source of safety in pits where they had wooden guides. He had had no personal experience, however, of safety-catches in operation with wire-rope guides, although he had seen working-models; but he was optimistic, and hoped that in the future there would be safety-catches that would do as good work as the disengaging-hooks. But exhaustive experiments would have to be made, say in some disused shaft, to find out wherein their defects lay.

The PRESIDENT said that the thanks of all the members were due to the author of a paper so valuable in itself, and which had led to so much interesting and instructive discussion.

Mr. GEORGE H. WINSTANLEY said that he would like to express his thanks to Mr. Dickinson for bringing to bear his very extensive knowledge and interesting reminiscences on so important a subject, and he was exceedingly sorry that Mr. Dickinson was not present on the occasion when the paper was read. The remarks of Mr. Dickinson and Mr. Harrison, with regard to safety-cages, could be dealt with in the same breath. The safety-catches in use at the present time—those that had undoubtedly, now and again, saved a falling cage—were at old collieries where the speed

of winding was comparatively slow, where the load was comparatively small, and the conductors made of wood. They had, however, to face, not the conditions of the past, but those of the present and the immediate future. For every colliery with small shafts, wooden conductors, and slow speed of winding, with comparatively small loads, there were several collieries with deep shafts, high speeds, and heavy loads; and the problem of arresting the downward movement of a comparatively slow-moving cage, of moderate weight, and that of arresting the movement of a cage weighing 10 or 12 tons, moving with terrific velocity, were widely different. He was afraid that it would be a long time before they could get a safety-device—which he would be most eager to welcome—that in the event of accident would take charge of the cage, not attempting its sudden arrest, but controlling it till it came safely to rest. To arrest a heavy body, moving at a high velocity, was a dangerous operation. Nearly all the safety-catches now in use tended to stop a cage where the velocity was not so high as to produce destructive effects, and these might answer the purpose at the places where they were used. The fact, however, should not be lost sight of, that whatever experiments were undertaken they must, as in those recorded in the Report of the Transvaal Commission, be with full-sized appliances, under ordinary conditions, and moving at ordinary winding speeds, and not with models. The Transvaal report was on the whole unfavourable to safety-cages. Of four safety-devices experimented with, it gave a sort of qualified [redacted]

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE REINDEER HOTEL, DONCASTER, MAY 27TH, 1908.

MR. W. WALKER, PRESIDENT, IN THE CHAIR.

The minutes of the Joint General Meeting held on April 7th, 1908, were read and confirmed.

The following gentlemen, having been duly nominated, were elected:—

MEMBERS—

Mr. GODFREY M. MAY, Mechanical Engineer, Broad Oaks Iron Works, Chesterfield.

Mr. DAVID THOMAS PROTHEROE, Colliery Manager, Ackton Hall Colliery, Featherston, near Pontefract.

ALTERATIONS IN THE RULES.

Notice was given of alterations in Rules Nos. 4, 5, and 7, to be proposed at the general meeting to be held in July next.

The PRESIDENT (Mr. W. Walker) gave notice that on the copies of the proposed Rule No. 5, which had been circulated amongst the members, the words "six months shall" should read "six months may."

MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

EXCURSION-MEETING, MAY 27TH, 1908.

A visit was paid to the works of the Great Northern Railway Company, Doncaster. In the absence of Mr. Ivatt (Superintendent), Mr. Wintour received the members, who were conducted through the fitting, constructing, and repairing shops, foundries, and carriage-building shops.

The PRESIDENT (Mr. W. Walker) proposed, and it was unanimously agreed, that the best thanks of the Institute be given to the Great Northern Railway Company for their kindness in allowing the members to inspect the works.

The members afterwards visited Frickley colliery, at the invitation of the Carlton Main Colliery Company, Limited.

A vote of thanks was passed to the Colliery Company for their kind invitation and hospitality.

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10,000 gallons per hour, against a head of 810 feet. It is intended to add another pump to duplicate this, but that will be a motor-driven three-throw pump. A small pump is also to be fitted in the sump below the Barnslev seam, for pumping the water collected in the shaft below the Shafton seam into water-tanks in the workings. This water amounts to about 500 gallons per hour, and the pumps will be of the centrifugal type, with 2-inch inlet, and motor-driven.

Sinking Engines.—Both pairs of sinking engines have cylinders 26 inches in diameter, with a stroke of 5 feet, and drums 12 feet in diameter and 9 feet wide, keyed on the crank-shafts, and fitted with steam- and foot-breaks, worked independently, and steam-reversing engines. The pair of engines at the No. 2 or upcast pit are now winding coal at the rate of six full tubs per wind, each tub holding 10 hundredweights.

Winding-engines.—These have cylinders 48 inches in diameter, with a stroke of 7 feet 6 inches, and a winding-drum 24 feet in diameter by 12 feet in width. The engines are fitted with Cornish double-beat valves and steam-reversing gear. The Barnes-and-Markham patent automatic cut-off is also fitted. The cages are made to hold twelve tubs, six on each deck, and are guided by lock-coil ropes, 1½ inches in diameter, six to each cage, and two similar ropes hung between the two cages. The winding-ropes for these cages will be of the lock-coil type, 6½ inches in circumference, and fitted with Elliott patent rope-sockets. The winding-ropes at the upcast pit are also of the lock-coil type, 4¼ inches in circumference, and are fitted with the same type of socket.

Headgear.—The headgear at No. 1 or downcast pit is made of steel. It is 56 feet high and the main legs are 2 feet 3 inches square, the corner angles being 5 by 5 by ⅝ inches. The headgear pulleys are 20 feet in diameter; the headgear at the upcast pit is made of wood, but preparation is made for erecting a steel headgear at a later date.

Ventilation.—The ventilation is produced by a Walker "Indestructible" fan, 24 feet in diameter, driven by vertical compound engines, with valve-gear of the Corliss type. The high-pressure cylinder is 23 inches in diameter, the low-pressure

cylinder 38 inches in diameter, and the stroke 3 feet. The drive is by thirteen cotton ropes, $1\frac{3}{4}$ inches in diameter. The crank-shaft pulley is 15 feet in diameter, and the fan-shaft pulley 9 feet in diameter. The fan is designed to exhaust 400,000 cubic feet of air per minute at a water-gauge of 4 inches, when the engines are running at 60 revolutions per minute. At present the fan is exhausting 150,000 cubic feet per minute with a 1·3 inches water-gauge.

Boilers.—There are twelve Lancashire boilers, each 30 feet long and 9 feet in diameter, working at a pressure of 120 pounds per square inch. They are fitted with Bennis mechanical stokers and firebars, the coal being supplied to the latter by creepers from a bunker. The return-chain of the creeper conveys the ashes into wagons.

Electric Generator.—The generating plant at present consists of one unit, as follows:—A 250-kilowatt alternator, direct-driven at a speed of 375 revolutions per minute by a Belliss-Morcom 3-cylinder engine, developing 360 brake horsepower. The current is three-phase, at a voltage of 550, the periodicity being 50 cycles per second. It is intended to instal, as a duplicate set to the above, an alternator direct-driven by an exhaust turbine, using the steam from the fan-engines and haulage-engines, and working in conjunction with a large condenser. The switchboard is constructed of enamelled slate, with generator-

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run from the cages, through the tipplers, and back to the cages, without any handling or tub-creepers. All the screening machinery is driven by electric motors. At present, the coal is being drawn up the upcast shaft, and from this shaft it is conveyed by a novel tub-creeper, 266 feet from centre to centre of drums, to the screens, and is then hoisted to the proper level by a steam-hoist. The empty tubs are hauled back along the gantry by the return-chain of the tub-creeper.

Air-compressors.—There is also in course of erection a horizontal compound air-compressor, with a high-pressure steam-cylinder, 27 inches in diameter; an air-cylinder, 26½ inches in diameter; a low-pressure steam-cylinder, 49 inches in diameter; an air-cylinder, 43 inches in diameter, by 5 feet stroke, fitted with Corliss valves and intercooler, and made to deliver air at a pressure of 100 pounds per square inch.

Haulage.—The present underground haulage is of the endless-rope type, worked by means of the engines which previously worked the sinking-scaffold capstans, and have cylinders 13 inches in diameter, with 30 inches stroke, being geared 11½ to 1 to a surging-wheel 8 feet in diameter, working a strap-rope down the shaft. This strap-rope is 1¼ inches in diameter, and drives a vertical shaft in the pit, with surging-wheels 6 feet in diameter, fitted with friction-clutches. There are three endless ropes at present working, all driven by the one strap-rope, one being 1 inch in diameter, about 1,500 feet long, and this again drives two other ropes ¾ inch in diameter, each about 1,500 feet long. This haulage is really temporary, as the permanent haulage will be driven electrically and by compressed air, as before mentioned.

Miscellaneous.—A lamp-room is being erected to hold 3,000 lamps, which are of the Thorneburry type. A substantial block of workshops, 240 feet long by 50 feet wide, has been erected, and comprises blacksmiths', fitting, and carpenters' shops, as also a saw-mill, all well stocked with machinery. A store-room, 70 feet long by 50 feet wide, is also erected. The stables contain loose boxes, stalls, coach-houses, and an electrically-driven forage-plant, consisting of chopper and three crushing mills for corn, beans, and peas, and large enough to deal with one week's food-supply for 150 horses in one day. Two six-wheeled coupled locomotives,

with cylinders 12 inches in diameter and 18 inches stroke; and another with cylinders 18 inches in diameter and 24 inches stroke, will shortly be at work. A water-softening plant, for dealing with 15,000 gallons of water per hour, is being erected, and this will also raise the temperature of the feed-water to 180° Fahr., the exhaust steam from the winding-engines being used to attain this end.

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THE NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE COUNTY COUNCIL MINING SCHOOL, STOKE-UPON-TRENT,
JUNE 1ST, 1908.

MR. A. M. HENSHAW, PAST-PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, which were confirmed and signed.

Mr. ALFRED REDFERN read the following "Practical Notes on Deep Shaft-sinking and Breaking Ground on the Witwatersrand":—

PRACTICAL NOTES ON DEEP SHAFT-SINKING AND BREAKING GROUND ON THE WITWATERSRAND.

By ALFRED REDFERN.

Introduction.—Several deep shafts are at present in process of being sunk on the Rand, whilst others are nearing completion. These are frequently called the "fourth row of deep levels," and are on the largest scale yet attempted, considered in respect of area of opening, and hauling or winding capacity.

These shafts are of rectangular shape, timbered throughout, and divided into seven or eight compartments. Timber is the best medium for securing the sides in rectangular shafts. It is most expeditious for fixing, as both sinking and timbering operations are carried on simultaneously. It has a long life of service, Rand conditions being exceptionally favourable, as the shafts are fairly dry, and the sides usually strong ground.

Given good workmanship, and treatment with creosote or other preservative compound, the timber will last the whole life of a mine of large area, without renewal. Thus, by the preserving rather than the rotting action of the water met with, and owing to the uniform hardness of the ground, it is rarely necessary to

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extreme dip. The advantages of this method are obvious:—(1) The reef is more quickly reached, that is, with a minimum of vertical sinking and dead work. (2) The mineral from the upper levels may be won while the incline shaft is being sunk and the lower levels developed; in short, the productive stage is more rapidly attained. Ventilation is also simple, nearly all gold-mines on the Rand being ventilated naturally; even in the sinking of deep shafts, mechanical ventilators are rarely used.

The disadvantages are the increased difficulty of hauling and pumping operations.

In discussing with eminent engineers this method of opening out, the writer found that they were consistently in favour of it, being strongly averse to working "backs," or rise-workings. The writer, in his experience, found that in rise-workings or "backs," if carried on to any great extent, the toll levied on human life from miners' phthisis would be serious, owing to the dryness of the ground producing large quantities of quartz-dust in the course of the extensive drilling operations. Ventilation difficulties would also arise.

The first and second row of deep "vertical shafts" were sunk with three to five compartments, having their longer axes on the line of the strike of the measures, and were continued as "underlay" incline shafts after the reef had been pierced. This order is changed in the larger and deeper shafts, as they are designed to be fed with ore from separate incline shafts, set away near the bottom of the vertical portion, and thus practically two-stage winding has been introduced. Hence the deeper shafts are sunk with their longer axes in the line of full dip, obtaining better results in sinking, draining, and in securing the sides, especially where bad ground may be met with.

Setting-out.—Two methods are in practice:—(1) A temporary headgear is erected, with two pairs of small winding-engines, to sink to a depth of 1,000 or 1,500 feet, or more. These are replaced by larger medium-sized engines, capable of completing the actual sinking, and possibly some initial development. In the meantime, the permanent steel headgear is being erected, over and outside the temporary one, and brought into use when completed. The erection of the three sets of permanent winders may be proceeded with also, behind the second installation of sinking winders. With this method, buckets or "bowks" are used.

(2) Using self-dumping skips. In this method sinking is not proceeded with, except as explained in the next paragraph, until the permanent steel headgear, with bins and chutes, and at least one set of permanent winders, are erected.

The details common to both methods are as follows:—The shaft is commenced of much larger area than the intended finished size, and sunk in this way down to the stone-head, or solid rock. That is, a shaft, in which the ordinary sinking area before timbering is about 50 by 8 feet, will be started 56 by 14 feet to 58 by 16 feet, in order to allow of the addition of strong masonry walls of stone and cement, or cement-concrete, 2 to 4 feet thick, or of sufficient strength to keep out effectually surface-water, and to form substantial foundations for the steel headgear and pulley-frames.

This walling also secures that portion of the shaft-sides most liable to deteriorate from weathering. The internal area of this masonry is the same as that of the excavated shaft below, seeing that the ordinary "sets" of timber are hung from the surface throughout. The first "bearer," or supporting set, has its cross-buntons laid across, or let into, the uppermost course of masonry or near it (fig. 2, plate xv.).

Sinking by Hand, Using Buckets or Bowks.—Where sufficient cheap labour is available, hand-sinking compares favourably with machine-sinking, both as regards economy and speed. After [redacted]

Training and Selection of Native Workmen.—The human element enters largely here. The first complement of natives or "boys" supplied by the Witwatersrand Native Labour Association, may be, to a certain extent selected; but, seeing that the South African native rests in the fullest sense, when at his kraal, very indifferent work is got out of him as a hand-driller for some weeks after his arrival at a mine, except in the case of old hands with previous experience. The biggest and most able are selected as boss-boys or foremen, and these, with the whites, assist and instruct the remainder.

Under fair treatment, the writer found most tribes to be honest with respect to property, and docile and quick to learn the ordinary duties of shovelling, drilling, and turning of holes, the last-named being the most difficult acquirement.

Division of Labour when Sinking.—When actually drilling, eighty and upwards may work at one time, but for "lashing" (cleaning out) sixty, or even less, will be sufficient, so that in the commencement of each shift twenty or more are engaged on the surface, tramming rock to the spoil-heap, carrying timber from the timber-yard to the shaft-collar, and in other duties on the surface until drilling commences.

So soon as blasting is completed, the two white men, each with several of the most active and experienced boys, descend in different buckets. The chargeman proceeds to the lighting platform, to lower the electric cable, with lamp attached, consisting of a cluster of incandescent lights, by means of a windlass, and to switch on the electric current, after having examined the lamp and replaced any broken bulbs. He then descends to the bottom sets of timber, and along with his partner's gang cleans the sets of all loose stones, and carefully examines the sides and blocking.

The corner-lines, four in number, are then lowered with plumb-bobs attached, each line being hung from the outside corner of the last set of timber that is permanently blocked and wedged in proper alignment.

The sides are further examined while the gangs are lowered from the timbers to the bottom, and then trimmed of loose hanging rock, while boys and tools are being sent down from the surface. Any loose rock found hanging out of reach is got down by the chargeman, from the bucket, a hammer and pinch-bar being used for the purpose. Then "lashing" commences, care being

taken that the buckets are not overfilled, a space of not less than 6 inches being left from the top. When steadying the bucket before the final signal is given, extra care must also be taken to see and feel that no stones are sticking to the hollow bottom and ring or handle, seeing that smooth-bottomed sinking buckets cannot be used, as they have to serve for attaching ropes to lift the wall-plates into position during the timbering operations.

"Lashing" out usually occupies 2½ to 3½ hours, according to the nature of the ground and the quantity of *débris*. During this process, the chargeman must keep a keen look out for misfired holes (which are carefully plugged with noticeable plugs) and for old sockets, or bottoms of holes, as these often contain unexploded gelatine. This precaution is rendered doubly necessary, as both boys and coolies are great offenders in the matter of drilling in them, and by far the greatest number of fatal accidents reported are due to this cause. The boys, if not carefully watched, will often leave a point, where they have been directed to drill, to commence in the holes left by misfires.

If the ends of the shaft are not keeping pace with the sump, or if one end is sumped more than the other (this being often the case when strata of variable hardness are being sunk through), then the white miner erects a temporary platform across the end, by wedging a 3-by-9-inch plank across, so that three or four boys may be started to drill early in the shift; and by this arrangement longer holes are obtained in the hardest ground. When

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compartments not in use for winding rock from the sinkers. These scaffolds also serve as a protective covering over the sinkers below. The bottom set is not permanently blocked and wedged until another set has been hung below it. With this practice it may be seen that the operation of securing each set is performed from above and below at the same time.

All the timber used for sets is either pitch-pine, Oregon pine, or Kauri pine of New Zealand and Australia. Each set consists of 31 pieces, as under (figs. 1, 2, and 3, plate xv.):—

Horizontal:—

- Four half wall-plates, 24 to 25 feet by 9 by 9 inches (fig. 7).
- Two end-plates, 7 to 8 feet by 9 by 9 inches (fig. 6).
- Six dividers, 5 feet 6 inches to 6 feet 6 inches by 6 by 9 inches, DD (figs. 1, 2, and 5).
- One divider, 5 feet 6 inches to 6 feet 6 inches by 4 by 9 inches, D' (figs. 1 and 2).

Vertical:—

- Four corner-studdles, 5 feet 3 inches by 9 by 9 inches, CS (fig. 3).
- Fourteen side-studdles, 5 feet 3 inches by 4 by 11 inches, SS (fig. 3).
- Eight pairs of hanging-bolts, 1¼ inches round iron (fig. 3). Length over a pair, hung, 7 feet 2 inches.

The wall-plates in a rectangular shaft correspond to the curb or crib in a circular shaft, and to the bar and sill in a timbered incline. Each wall-plate is sent down in halves, or nearly halves, the joint being made to coincide with a compartment division; thus the two halves for one end may be 27 feet, while the two halves for the other end may be only 24 feet long. The two halves are joined by a vertical half-and-half cheek-joint, secured with two bolts; the middle of the joint, which is 18 inches long, is behind the divider, and underneath the studdle nearest the centre of the shaft. The upper and lower surfaces of the wall-plates are recessed, or countersunk, to receive the studdles, and the internal face is dovetailed, V-shape, to receive the dividers. At the ends of the wall-plates, a horizontal half-and-half joint is made with the end-plate.

Operation of Hanging a Complete Set in a Shaft of Eight Compartments.—There are in use two hauling or winding-engines and one crab or capstan. The wall-plates are lowered down the central compartment, one half at each wind, by the capstan-engine.

An electric signal is in operation from the timbers to the engine-house, when lowering wall-plates, this being used for the capstan-engine only. While sets are being lowered, the wires

of the mechanical signals are raised a few feet from the shaft-bottom to prevent the boys from interfering with them.

The timber gang, consisting usually of two white men (in some shafts four), and ten or twelve boys, proceeds to the bottom set of timber, taking eight pairs of hanging-bolts, four scarf-bolts for the wall-plate joints, spanners and hammers, the last-named having the handles fitted with a loop of cord, to slip over one wrist when using, and to hang the tool on the nearest hanging bolt when not in use; also a length of stout rope, fitted at one end with an eye-bolt and nut, the bolt being 1 foot in length. On the surface, the first half of a wall-plate is attached to the capstan-rope with a long D link, and raised until it hangs steady over the centre of the compartment, then lowered rapidly, but with uniform speed, until stopped by a signal at a convenient point for inserting the first pair of hanging-bolts, and the eye-bolt attached to the rope already mentioned, which has been passed underneath two dividers and secured to the ring below the bucket nearest that end of the shaft where the wall-plate is to be hung. It is then further lowered, and the second pair of hanging-bolts is inserted, and lowered again until the end forming the middle joint of the finished wall-plate is about 4 feet below the bottom joint of the finished wall-plate is about 4 feet below the bottom set.

By this time, the rope attached to the bucket is taut, and the outer end of the wall-plate swung towards that end of the shaft. The bucket is then raised until the wall-plate hangs evenly at

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If two sets are to be hung at one operation the two pieces marked No. I. are sent down and hung, one below the other, then the two marked No. II., and so on. After the wall-plates are hung, they are firmly bolted at the joints near the centre, forming one complete plate along each side of the shaft. The capstan-rope and engine are then no longer required, and the timber gang divide, half going to each end of the shaft. They first reach down the scaffold-planks from the set above, and form a new scaffold on the wall-plates just hung, in the manner already described.

By this time the outside bucket at each end has been sent down, containing the end-plates and dividers. These are off-loaded on the scaffold, or lifted direct into position. The end-plates are first fixed, and an 8-inch wire-nail driven in each end to prevent slipping. The dividers are fitted with a clip or hanger at each end passing over and clipping the wall-plates, These clips are made of 1 by ⅜ inch flat-iron and are secured with two ½-inch bolts passing through the divider (fig. 5, plate xv.). They effectually tie the set, horizontally, until permanently secured by blocking and wedging, when they are taken out and used again.

Next come the studdles or distance-pieces; the first bucket is off-loaded on the scaffold and sent away; starting at the ends, the corner piece with first and second pieces along one side are fixed, and held by hand while the hanging-bolts are tightened with a large spanner, then the corner, first, and second pieces on the opposite side are similarly secured. If the second studdle is not readily secured by tightening the hanging-bolt in the first instance, then all the pieces along one side are fixed, and firmly secured by tightening all four pairs of hanging-bolts along that side, and the same on the other side. This completes the operation of "hanging" a set of timber. One winding-engine may now be released to be used by the sinkers, and the wires of the mechanical signals are lowered.

Blocking and Wedging.—Each set is adjusted in proper alignment, and firmly secured with pitch-pine blocks and dry soft-wood wedges. The blocks measure 9 by 9 inches, and are cut to lengths to suit the spaces between the wall-plates and the excavated sides. In an eight-compartment shaft, each set is blocked at twenty-two points, namely, along the sides, in line with dividers and end-

plates, and at the ends, in line with the wall-plates. All blocks are slightly inclined downwards from the set to the rock. This effect is obtained either by cutting the blocks obliquely at the ends, or by nailing wedges to them. Blocks are never placed behind the wall-plate at the centre of a compartment.

Thus it will be seen that each set is made practically self-supporting, and if the hanging-bolts break, there is no danger of the timber falling away. In fact, in some shafts the hanging-bolts are taken out and used again, but the writer deprecates this practice.

Sinking Resumed.—When the timbermen release the buckets, any water present may be baled, when the boys who have finished their drilling task are allowed to ascend.

The usual depth of hole drilled by one boy, single-hand, is 3 feet, using a 4-pound hammer, with a handle 16 inches long. When double-hand, one boy turning, and the other striking, a hole 4 to 4½ feet deep is drilled, using a 7-pound hammer, with a handle 2 feet long. The holes are cleansed with a pump of simple design, that is, a straight piece of pipe a little less in diameter than the finished size of the hole, and 4 to 5½ feet in length.

Charging.—About an hour before the fixed time for firing, the chargeman, having prepared the cartridges and fuses, brings them from the magazine on the surface to the shaft-bottom, and with his partner commences charging the holes already drilled, starting from each end of the shaft. Each hole is measured, and

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ridge is then inserted above the primer, and pressed home. Although water-tamping is sufficient, most holes being under water, small pieces of sacking are pressed down tight on the charge, to prevent the cartridge from floating, or being dragged out. The fuses are sometimes prepared by the banksman, but sinkers prepare their own if they prefer to do so.

The writer has known many misfires occur owing to the person preparing the fuses squeezing the detonator so tight with the nippers, in fixing it to the fuse, that the powder-train has been divided.

When all the holes, usually fifty to sixty, are charged, torch-lamps are lighted, and one white man ascends in the bucket to the lighting-stage, switches off the current, and winds up the cable, with lamp, or cluster of incandescent lights. In some shafts, these are raised by the banksman with a windlass, when the sinkers have signalled "clear," after lighting up. When all is ready, a pre-arranged signal (usually five knocks or rings) is given for blasting. The engineman answers by raising the bucket a few feet, and lowering it again steadily until it rests evenly on the bottom. If the bucket does not rest firmly, the blasting-signal is repeated, and a firm resting-place made while the answer is being given. The chargeman then instructs his assistants as to the order in which the fuses must be lighted, and gives the word "fire." The chargeman lights the central row of sumpers, and takes care that the others do not get in front of him in lighting the side-holes.

On the coolness and dexterity of this lighting-up operation, the success of a blast often depends; for, if each shot is lighted in proper order, the stone is released in definite and pre-arranged sequence, and with the maximum effect from the explosive.

It is a good practice to burn a warning fuse, that is, a fuse of equal length to those used in each charge, and hung over the side of the bucket. It is lighted immediately before the first shot, and, from its rate of burning warning may be given by the boy left in the bucket to hold the signal-wire. The chargeman is the last to travel the length of the shaft, noting, in passing, if all the fuses are burning, and then he climbs into the bucket and gives the final signal "clear."

The relieving chargeman usually meets the men coming off, at the shaft-mouth, and together they count the reports as the

charges explode. The man coming off states the number of holes drilled, charged, and lighted, and compares the same with the reports of shots that have been counted.

When a considerable depth, say 2,000 feet is reached, a pent-house is formed in one of the compartments not in use for winding, at about half way, and the sinkers are raised to this point after lighting up, until the reports have been counted, when they ascend to the surface. In some cases, where a blowing fan is installed, and the shot-firing does not always occur at the end of the shift, the men are immediately and rapidly lowered to the bottom again, passing through the intermediate zone of foul gases.

Then "lashing" is proceeded with as soon as the inspection has been made. This is rendered possible by the rapid rising of the smoke and heated fumes from the explosive and fuses, leaving the shaft-bottom fairly clear. In the large area of the shaft, the foul gases are quickly diffused and carried away.

Natural ventilation, however, is often sufficient, and is fully taken advantage of, by fixing a brattice of tongued and grooved boards throughout the whole depth of the shaft—sometimes in the centre, but more often between the pumping compartment and the next hauling-compartment. In this case the brattice may be continued from the surface-level up to the pulleys as a smoke-stack, giving an increased upcast column.

Putting in Bearers.—These are inserted at regular intervals, [redacted]

prepared after the timber reaches that point, when they are finished by chiselling or careful blasting. The baulks or bearers consist of pitch-pine or some other hard wood of great strength, 11 to 12 feet in length, 9 inches wide, and 12 inches deep. A bearer may consist of two such baulks, one above the other, of a depth to fill the recess or hitch prepared. Three, four, or even seven, may be put in to support a bearer-set, but four is most usual. Great care is taken to ensure perfect levelling and vertical alignment, for the alignment of all ordinary sets below is taken from last bearer-set.

Perpendicularity of the Shaft.—To keep the shaft truly vertical, a projecting beam or hinged arm is fixed on the surface at a convenient point near each end of the shaft, with a fine tube or pulley at the outer end for guiding a very fine piano wire, to which a plumb-bob is attached and lowered from a small hand-reel. The plumb-bob is shaped like a boy's peg-top, and the wire is threaded through the screwed top. The wire hangs at a known distance, say 8 inches, from both wall-plate and end-plate, inside each end-compartment. It is lowered when fixing bearer-sets and at fixed periods, as the sinking and timbering proceeds. Intermediate sets are lined by off-sets from the bearer-sets.

In another system, four plumb-lines are used, two in the centre of the end-plates and two in the centre of the wall-plates, hung from each bearer-set, as these are successively put in, and maintained at a distance of 3 inches clear by nailing a bracket on the plates of each bearer-set; a saw-cut is marked exactly in the centre of the end-plates, and by sighting along the shaft from end to end, the saw-cuts and plumb-lines are wedged up to alignment, the wall-plates being wedged up to line in the same manner.

Working the Reef and Breaking Ground.—In deep vertical shafts, the sinking is usually continued for some distance below the reef. In combined vertical and inclined shafts, this distance varies from 50 to 80 feet.

With separate inclines, however, it is a good practice to continue the vertical shaft to a depth, equal to, and on the same level as, the first station or cross-cut on the incline-shaft. A connecting-drive may then be driven from the bottom of the vertical shaft to the ore-bin at the first station in the incline. This facilitates

the cleaning-out of spilled rock from the vertical shaft-bottom in ordinary work, and is useful in case of accidents and repairs to the shaft.

At one deep mine, the writer knew of two overwinds in one month's working, each resulting in the parting of the winding-rope and the skip being precipitated to the bottom, without damage to conductors or loading-bins on its passage; and in each case, owing to the shaft being sunk far enough beyond the lowest loading-station, the ropes and skips were replaced by new ones, and work resumed with the loss of one shift only, while the damaged skips were recovered at leisure.

Inclined shafts are invariably sunk, or driven, "underlay" in the country rock, parallel to the reef, and about 40 feet below it. At intervals of 100 feet (sometimes more), cross-cuts are driven from the shaft to the reef, and ore-bins formed in the intermediate ground (fig. 4, plate xv.). Winning-levels, or drives, are then driven east and west on the reef. If the several "leaders" are separated by a considerable thickness of ground, levels are driven in each; if close together, they are worked from one drive by means of box-holes or chutes. By this arrangement, the stoping of the reef may be continuous, that is, no special shaft-pillars need be left, whilst stoping may go on simultaneously with the extended sinking of the shaft.

The driving of the levels is usually carried on by means of compressed-air machine-drills. The machines in most general use are the Ingersoll, Slugger, Climax, and Hercules, the first

[redacted]

the winzes from upper levels. A winze is best sunk by hand, the "boys" lashing out, and drilling over during each shift, as in shaft-sinking. The rock is raised from a winze by means of a hand-windlass and bucket, or by a compressed-air winch and small skip.

Raises are best driven by machine, seeing that all the holes are drilled dry, and the broken rock gravitates to the level below. Usually winzes are sunk two-thirds, and raises driven one-third of the connecting distance.

During all development-driving, in levels, winzes, and raises, samples of the reef exposed are regularly taken, and values recorded in pennyweights per ton over so many inches of stoping width. Thus the approximate value of a mine is ascertained in advance of the actual stoping.

In mines of great depths and large areas, owing to the scanty information obtained in advance of sinking by costly bore-holes, it is necessary to block-out large areas and ascertain values, before the crushing and cyanide plants are erected.

Methods of stoping depend largely on the inclination and thickness of the reef, and also on the thickness of unproductive rock between the leaders. On a reef over 4 feet wide, machine-drills are economical, but where the width is less, the reef is extracted more cleanly by hand-drilling.

To overcome the difficulty of comparative scarcity of cheap labour, small machines have been introduced, to drill a hole similar to that drilled by hand, 1 inch in diameter and from 3 to 4 feet deep. Up to recently, however, in the writer's opinion, no satisfactory drill for this class of work has been put on the market, although experiments have been conducted for several years in this direction. The Gordon drill may possibly have the best claim to success in this matter, yet the manufacturers state that they are still making improvements.

Stoping.—Two methods are in general practice, modified to suit local conditions, namely:

(1) *Overhand.* (Fig. 4, plate xv.).—Where a level must be used for haulage after the reef above has been stoped away, an intermediate drive is carried above the main drive, and connected every 30 feet by box-holes, the openings of the latter being of small area in steep ground, the better to control the loading of rock into trucks through the chutes.

Stoping is usually commenced from the sides of a winze, and in this case the intermediate drive is kept 40 or 50 feet in advance of the bottom of the stope. Benches or stopes are formed until the stoped face extends to the next level above; pillars of reef are left in the stope and immediately below the upper level, connection-holings being put through as often as necessary.

No general system is adopted as to the proportion of reef to be left for safety-pillars, each mine overseer using his own discretion, and giving orders where pillars shall be left; even then, the size of such a pillar is often left to the miner. The hanging and footwalls are usually of great strength, and stand for many years, if sufficiently supported. In most cases about 15 per cent. is considered ample. No attempt is made to recover the pillars left.

In the flatter mines it is becoming the practice to sort the waste-rock underground, and build round packs or pillars with it as additional support to the hanging-wall. When above 45 degrees the broken ore is not all loaded out of the stope immediately, but sufficient is left to fill the stope and keep the benches within reach, until the top of the stope-face is so far advanced that the whole of the rock may be loaded away with safety.

When nearing the boundary or starting towards home, a timber roof or stooling is formed over the level instead of pillars being left.

Stout timbers, 10 inches to 1 foot in diameter, are set in [redacted]

of the stope advances. The practice, with a pair of machines, is to work three or four benches from the top downwards to the bottom, and then reverse the work upwards.

At some mines, a face is maintained more in line with the full dip, next three or four benches are worked downwards from the top to the bottom, and then the machines and gear are trammed out to the shaft, hoisted to the upper level, taken in-bye again to the top of the stope, and the process repeated. In the case of hand-drilling in a highly-inclined underhand stope, with a gang of thirty to forty boys, seeing that they are distributed over the whole length of the stope-face, it is necessary to clean down all broken rock to the bottom before drilling commences; because, owing to the inclination, any loose rock started from above, would prove dangerous to the boys working below. Under the Mines Act, all loose rock must be removed from the face before drilling commences. With machine-drilling, it is only necessary to clean the broken rock from those benches that are in process of being drilled, and situated above.

In a stope 6 feet wide, each machine is calculated to produce 8 tons of broken rock per shift, drilling four holes. The writer has seen this average nearly doubled over long periods, with six holes per machine per day. The average production from boys hand-drilling amounts to 15 hundredweights per day.

Driving is paid for by the lineal foot, and stoping work by the square fathom, based on areal measurement taken along the line of the reef; the pillars which have to be formed are paid for as if extracted, so as to cover the cost of the extra driving around them; or driving footage price is paid for the length of one side, or the length in the line of the full dip.

The CHAIRMAN (Mr. A. M. Henshaw) said that the paper was a very interesting one, and the details given showed a complete mastery of the subject. He should like Mr. Redfern to explain the difference between figs. 1 and 2 (plate xv.); in one case there was the natural formation of the side, and in the other there was masonry built around. He was struck by the remarks as to ventilation, and by the statement that there was nothing but natural ventilation. It seemed to him very extraordinary that that should be so, when depths of 4,000 feet and over were referred

to. He was interested in the blasting operations described, for when they came to consider that there were eighty men working in one shaft, they realized what the blasting operations were likely to be. Mr. Redfern, however, did not tell them how many shots were prepared in one shift; how they overcame the difficulty of the smoke from these shots in the absence of ventilation; and how soon the next shift could go on after firing a round of shots. Then, again, he (Mr. Henshaw) did not understand whether the whole of the men were brought out of the shaft when firing shots. Some mention was made of a penthouse half-way up, but he did not understand whether it was for the workmen or for the shot-firers only. Further, he understood that the sets of timber were being put in the shaft at the same time that sinking and drilling were going on. There was a great deal of timber to go in, and the work must be proceeding very busily at the same time that the men were working at the bottom. He did not see how they could obtain any proper protection above their heads, and he should therefore like to ask whether this was not a very dangerous practice.

With regard to drills, the necessity for a good small drill was, he thought, quite as pressing in this country as it was in South Africa. He was reading not long ago a very interesting account of experiments and tests made there with several drills, and he believed that the Gordon drill succeeded in obtaining the first prize; indeed, so far as he could understand from the de-

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Mr. JOHN CADMAN (H.M. Inspector of Mines, Newcastle-under-Lyme) said that Mr. Redfern had brought forward a paper which was particularly interesting. He should like to ask Mr. Redfern whether he had any information as to the temperatures, the conditions under which the men worked, the amount of clothing worn, and the quality of work done at the depth of which he had spoken. He (Mr. Cadman) claimed to have some little experience of the African negro, as found in the West Indies, and perhaps Mr. Redfern would be able to endorse, or give some information on, the point to which he was about to refer. The negro was a man who was quite competent to carry out work, provided that he was shown step by step all the details connected with that work; moreover, he must be paid by the piece, not by time. The want of any initiative whatever was a great failing in his character.

Mr. Redfern had referred to blasting operations. His account certainly seemed like a Jules Verne story; to light sixty to eighty fuses and then be able to get away without accident seemed to him (Mr. Cadman) a very difficult operation. Could Mr. Redfern give any information as to any accidents occurring by this operation, and what special precautions were taken to prevent them?

A matter which had always struck him in metal-mines was the want of underground haulage. Was any systematic haulage in use underground at the mines referred to in the paper?

He should also like the writer of the paper to inform him whether there was any factor which decided when overhand or underhand stoping was to be adopted.

Mr. J. T. STOBBS (Stoke-upon-Trent) said that he was very much interested in the paper, and he thought that they would agree that it was a valuable record of unique mine working. On the Rand they found strong mining companies, and the finest engineers—practical and theoretical—and quite modern plants, so that they had just the conditions under which they would expect to see the very best mining practice.

He took it for granted that the experts on the Rand, who were putting down these large rectangular shafts, were of opinion that they were the best shafts for the work—that was, for the rapid and successful exploitation of the reef. The paper was full of information, and he considered it one of the best that they had

had read before their Institute for many years. It was a distinct addition to mining literature, and would constitute a reference-paper for those who had to teach mining and who had to describe shaft-sinking under conditions such as they had no opportunity of seeing, when consequently they had to fall back on such records as this paper. If he might refer to the question of the reef, of which they saw a sample on the table, he would say that if people wanted to know whether mining was advancing as an art or a science, they could not do better than look at that sample, which was the material out of which fortunes were extracted on the Rand. No better example existed of the successful prosecution of mine-engineering than that. Out of this hard, unpromising material, vast profits could be realized.

Mr. F. H. WYNNE (Newcastle-under-Lyme) said that he was sorry to add one or two questions to the already large number that had been put, but he would like to know whether Mr. Redfern had any plan of the bottom of the shaft, showing the disposition of the shot-holes. He would also like to ascertain the order in which the shots were fired; whether the ground sunk through was anything like the stone that composed the reef, and was solid and sound all the way down; and whether Mr. Redfern had any figures relating to accidents due to timbering. It seemed to him that some of the thousands of separate pieces of timber required to line shafts of such a depth must be sometimes dropped, through mishap, while fixing in position, and it seemed

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Mr. JOHN CADMAN said that the majority of pits in Scotland were rectangular.

Mr. WOODWORTH remarked that natural ventilation alone was not deemed sufficient in such cases.

Mr. ALFRED REDFERN (Newcastle-under-Lyme), in replying to the discussion, said that the largest number of shots that he had lighted at one lighting-up operation was seventy-two, and the members could imagine that there was not much time lost. Out of the seventy-two shots, he had lighted twenty-five to thirty himself. The average number of shots fired at a time was, however, about 50; in one shaft in which he was working it was 56, and in another about 40. Then, as regards the natives, all of them were called "boys," and were allowed to ascend as soon as they had finished drilling their holes; and all except the two white men and three boys went to the surface before blasting commenced. With reference to safety-pillars, there was no law on the subject, and there was no regular practice. Supposing that a piece of ground was very rich, and sufficient pillars were left after the first working, and that afterwards a reef of lower grade was being worked, then the rich pillars were robbed to bring up the average value. Occasionally blocks of ground had been lost through caving. Usually in the case of large cavings of old stopes considerable warning was given by the noise of the moving ground, sufficient to allow all the natives and workmen to get away from the seat of danger. With regard to the measuring of ventilation, there was one instance on the Rand, when a connecting-drive was made, of 22,000 cubic feet of air circulating per minute without artificial ventilation. In addition, there were one hundred air-drills working, and it was calculated that these each produced a further 70 cubic feet of air per minute. As to the conditions of work in deep mines, it was not necessary to take off anything more than the coat and waistcoat, despite the fact that the white man worked fairly hard in some of those mines. The shift only lasted 8 hours, and the work was by contract. Five boys were allowed to two machines—in rare cases six; and it required two boys to work a machine, leaving one boy to carry water and drills. One boy was scarcely sufficient, so that a white man must be running one of his machines nearly throughout the shift. He had a high opinion of the African native as a workman, when properly

treated. He was somewhat stubborn, and under unfair treatment was sulky; but under what he considered just treatment, he was a good workman. They had to be firmly treated and with justice. So far as the native putting in timber or doing such work was concerned, the law enacted that he should only be employed on unskilled work, and that white men alone should handle explosives or fire shots. The native was, therefore, practically engaged only in drilling and shovelling. In the case of machine-drilling, he had seen some peculiar misfires, where one hole had brought the ground away from another, and possibly cut the fuse off between the point of burning and the detonator. After the broken rock had been cleared up, the whole bench had looked as if completely blasted away, particularly if a man on the following shift went to drill the next bench behind. There was practically no system of underground haulage adopted on the Rand.

Mr. JOHN CADMAN proposed a hearty vote of thanks to Mr. Redfern. He had placed before them much useful matter, which would make a valuable addition to the records of the Institute.

Mr. W. STATHAM, in seconding the vote of thanks, said that he was delighted with the paper, which would, so far as North Staffordshire was concerned, be a standard reference as to Rand mining.

The vote of thanks was heartily accorded.

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THE MINING INSTITUTE OF SCOTLAND.

VISIT TO THE WORKS OF WELDLESS CHAINS, LIMITED, GARTSHERRIE, JUNE 10TH, 1908.

The members were received by Mr. Alexander G. Strathern, managing director of the Company, and were shown the various processes in the manufacture of weldless-steel chains.

After the inspection, a hearty vote of thanks was accorded to Mr. Strathern and the Company.

THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD AT GARTSHERRIE, JUNE 10TH, 1908.

MR. J. M. RONALDSON, PAST-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, who had been duly nominated, were elected:—

MEMBERS—
Mr. ANDREW WALKER BARCLAY, Victoria Works, Airdrie.
Mr. JAMES G. FARQUHARSON, Annbank, Ayr.
Mr. JOHN IRVINE, JUN., Minas Ronjas, Coronel, Chile.
Mr. WILLIAM KING, Old School House, Fordell, Crossgates.
Mr. MALCOLM LECKIE, Hardhill Terrace, Armadale Station.
Mr. THOMAS MENZIES, Walkinshaw Colliery, Paisley.
Mr. JOHN PATON, Motherwell Colliery, Motherwell.

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DISCUSSION OF MR. SAM MAVOR'S "NOTE ON TIMBERING ROADWAYS."*

Mr. JOHN MACLUCKIE (Larkhall) said that he had made a few simple tests on a small scale. The first test was made with a piece of Norway timber, 8 feet long by $3\frac{3}{4}$ inches in diameter, without the rope.

A chain was hung over the centre of the crown, and on the chain was fixed a square iron block which acted as a foundation on which to build the other weights.

The following observations were made in the loading process:—With a load of 10 hundredweights, the crown showed a bending of 4 inches from the horizontal; with 12 hundredweights, a bending of $4\frac{5}{8}$ inches; with 14 hundredweights, $5\frac{1}{4}$ inches; and with $15\frac{3}{4}$ hundredweights, $5\frac{1}{2}$ inches. This last weight broke the crown.

The second test was made with a similar piece of timber, the dimensions being the same, with the exception that the rope was fixed below the crown as follows:—Four staples were driven in to hold the rope tight to the crown at about 20 inches apart. The rope-ends were bent up over the end of the crowns and held down by another staple on each end; afterwards both the rope below and the ends turned over were held by glands to ensure that there would be no slipping.

The process of loading was accomplished in the same manner as in the first case. After the first 7 hundredweights were put on the crown, it did not bend in the same proportion, but afterwards, as in the case of the first crown with the increasing weight, and by way of comparison the following observations were made:—With a weight of 10 hundredweights the crown showed only a bending of $3\frac{1}{8}$ inches, as compared with 4 inches in the first case; with a weight of fully 12 hundredweights, $3\frac{1}{2}$ inches as against $4\frac{5}{8}$ inches in the first case: and with the total weight of $15\frac{3}{4}$ hundredweights, it only showed a bending of $3\frac{5}{8}$ inches as compared with $5\frac{1}{2}$ inches in the first case without the rope. In the last test, the weight was allowed to hang for three minutes, and at the end of that time the bend was $3\frac{7}{8}$ inches. The weight hung for a considerable time afterwards, but did not show any further signs of bending.

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 169.

With a view to testing whether the two crowns were of similar strength, the glands were slackened cautiously and the whole weight allowed to hang on the crown, which it did for a short while and until the rope began to draw through the staples, when it immediately showed signs of giving way and ultimately broke with very little increase of weight.

In a third test, the beam or crown was an old pitchpine slide, measuring 3½ inches square by 8 feet long, the span being the same. With a weight of 5 hundredweights it bent 1¾ inches; with 15 hundredweights it bent 2⅞ inches; and with 26¾ hundredweights it bent 3¾ inches, breaking with a sudden snap.

In a fourth test, the sticks, size, and span were the same, the rope being fixed on, but the method of fixing and the material used were different. In the first case there were four staples made of ¼-inch iron, which were fixed about 20 inches apart on the bottom side of the crown, the rope being fixed by putting a staple tight down on it at one end of the crown, and the rope drawn straight along the crown whilst the other three staples were fastened or knocked in as stated; afterwards the loose ends were turned back over the top, and glands put on.

In the second case, there were eight staples made of ⅜-inch iron, and these were fixed 1 foot apart. But prior to the fixing in of the staples, the rope was strained tight, and afterwards the staples were driven in firmly. The rope being well secured below, the ends were turned back over the top, and glands put [redacted]

With regard to the economic aspect of the question, much would depend on the cheapness of labour and the cost of timber, as also the mining conditions under which the system was applied.

To make twelve staples and cut and fix the rope occupied about 35 minutes of a man's and a boy's time, which at the present rate of wages would cost about 5d.; the iron for staples, 1½d.; coal and old rope, ½d.; making a total cost of 7d. for each crown.

Where the economy of using old ropes in the manner suggested came in, and would be most realized, would be in the labour saving. If the life of a crown could be lengthened by the use of an old rope for a period of six months, it might be the means of saving in oncost wages a considerable sum, which might have been spent in replacing wood and repairing roads during that period.

Mr. Thomas Thomson (Hamilton) asked whether the experiments made by Mr. MacLuckie were carried out on the surface, or in the pit.

Mr. MacLuckie replied that they were made on the surface.

Mr. Thomson said he thought that experiments of this kind made on the surface were worthless, and not in accordance with the suggestion contained in Mr. Mavor's paper. He (Mr. Thomson) had got some crowns of ordinary pitwood measuring 10 feet by 6 inches, and a ⅞-inch old wire rope cut up into 10-foot lengths. This rope was run along the crown, and fastened with a staple at each end and two along the crown, dividing it into equal distances. A dozen of these crowns were then put up with the rope on the under-side, and the props driven hard up so as to make the rope as tight as possible. These were put up alternately with another dozen of crowns of the same size, but without the rope, 12 inches apart. These crowns had been up for two or three weeks, and he had seen them that morning, and some upon which the ropes were put were broken and yet the ropes were holding them in their place; in other words, the weight seemed to be all on the ropes. Some of the crowns without the ropes had been broken and renewed. Judging from what he saw, he did not know how long the rope would last, but it seemed to him

that if the rope was put properly on the crown, and perhaps three or four staples put in along the crown to keep the rope in position, there was no doubt whatever that it would lengthen the life of the crowns very much. There was certainly a tendency of the rope to slip off (owing to the crown being round) when the weight began to come on, but he thought that by adopting the method already mentioned, namely, putting in more staples, they might keep the rope in its place.

Mr. James Barrowman (Hamilton) asked whether Mr. Thomson's difficulty might not have been met by doubling the rope on the end of the crown and returning it along the top of the crown, as suggested by Mr. Mavor in his note.

Mr. Thomson said that he was of opinion that, if that suggestion had been followed, it would have spoilt the contrivance altogether, as it was almost impossible to bend the wire rope round the ends of the crowns so that it would be tightened up properly. In addition, when the crowns were prepared with the rope on the surface and sent down the pit, it might be the case that they were too long; and, in order to save the trouble of making room, the general method was to cut a small piece off the crown, so that if the ropes were fastened on the ends as suggested by Mr. Mavor, then the trouble would be for the repairers or brushers shifting the rope, which would be very expensive.

Mr. James Kirkpatrick (Cambuslang) said that he had tried

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Mr. Robert Martin (Newmains) said that he quite understood the use of the rope on a flat crown. He rather thought that Mr. Mavor himself favoured the flat crown, with a recess for the rope. He should like to ask Mr. MacLuckie, however, how he had supported the ends of the round crown so as to prevent it from canting in his experiment. He did not see how the idea could be made to work underground with a $\frac{3}{4}$-inch rope next the roof on top of a $3\frac{3}{4}$-inch round crown and then a $\frac{3}{4}$-inch rope between the round crown and the top of the leg, unless there was a recess or groove in both roof and leg to hold the rope: otherwise it would be very tedious or impossible to set it, and, unless very well set, when the weight came on the crown would roll. The expense of grooving the roof and leg would add very much to the cost. The drawing shown was incomplete, as it did not include a roof.

Mr. MacLuckie said that he had seen the process carried out in the shops at his own colliery, and he was quite certain that he could get the same thing accomplished below ground with 3-inch timber. It seemed to him that there might at first be some little difficulty, but it could be easily got over.

Mr. Smellie (New Cumnock) said that it was his experience in timbering that the legs required as much attention as the crown.

Mr. Kirkpatrick said that his was a stoop-and-room working. They had, in his experience, a great deal less trouble with the legs than with the crowns: the flat crowns broke so very rapidly. The legs could be saved a good deal by pointing them at one end, so that when the heavy pressure came on they would simply fray up at the pointed ends.

The further discussion was adjourned.

DISCUSSION OF MR. ALEXANDER G. STRATHERN'S PAPER ON "HOW WELDLESS CHAINS ARE MADE."*

Mr. Thomas Arnott (Glasgow) said that, on looking over the works that day, he observed that a number of the links were

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 173.

cracked at the end. What was done with links of that description?

Mr. JOHN MACLUCKIE (Larkhall) said that, in connection with the tests made on the links and witnessed by the members, he noticed that it took 7 tons to break a ⅝-inch chain Would Mr. Strathern be good enough to tell them the exact point when the link began to draw or stretch?

Mr. JAMES BARROWMAN (Hamilton) said that, the members of the Institute having seen the operations of manufacture in the works for themselves, there was less need for discussion than would otherwise have been the case. He hoped, therefore, that Mr. Strathern would not consider it lack of interest if they did not have a long discussion.

Mr. GEORGE NESS (Glasgow) said that, in regard to the process which Mr. Strathern had introduced into the works, he noticed from one of the firm's lists that the factor of safety was 5. He would like to know whether that was the usual factor of safety applying to chains. His reason for asking that question was because of the fact that on page 180 of his paper, Mr. Strathern gave the working load as 30 hundredweights for a ½-inch chain, while in the list referred to he had put it down as only 24 hundredweights. It was evident that the two factors of safety were not formed on the same basis, because if it was 5 in the case of 24 hundredweight, it must be about 4 in the other instance. [redacted]

He had to explain, in answer to Mr. Arnott, that if any link in a chain was damaged, that link would simply be cut out, as it could not possibly be used; the chain would, however, be joined by a special connecting-link which they made for that purpose; or, if the length of chain was too short to be joined again, it would be laid aside to be utilized for other work where short lengths of chain were required. They had numerous enquiries for very short chains, sometimes amounting to only two links, so that there was practically no waste. If a flaw in any link was not detected by the eye, it would come out in the testing machine; the test-load there applied being double the Admiralty standard, such a load could not fail to eliminate anything that might be defective.

With regard to the question as to when the $\frac{3}{8}$-inch link began to stretch, he had to say that, even with the finest testing machine in the world, this was a very difficult point to arrive at with certainty. It was generally considered that about half the breaking-load to a little over would be the elastic limit. They might, therefore, take it that if a steel chain broke at 7 tons, it would begin to stretch somewhere about $3\frac{1}{2}$ tons.

Mr. Ness had mentioned that, in the paper, 30 hundredweights was quoted as the working-load of a $\frac{1}{2}$-inch welded iron chain while the working-load of a $\frac{1}{2}$-inch weldless-steel chain was given as 3 tons, and Mr. Ness wished to know why these figures differed from the tables issued by the firm. He would explain that it was clearly stated in the paper that the working-load was taken as one-fourth of the breaking-load, and in order to compare both types of chain fairly, the working-load was assumed in both cases to be one-fourth of the breaking-load. In the tables which his firm issued, the factor of safety was always given as 5; but since these tables were issued they had found that some of the makers of iron chains had apparently raised their working-loads and decreased their factor of safety. He could only assume that this had been done in order more nearly to approach the working-loads fixed by his firm.

With reference to the point also raised by Mr. Ness regarding the various prices at which iron chains were sold, he would point out that these variations arose on account both of the quality of material and of the workmanship. At the last meeting

he mentioned that a ¼-inch iron chain could be bought for as low as 19s. per hundredweight, but a price list had since come into his hands where a ¼-inch iron chain was quoted at 14s. per hundredweight. He left it to their imagination to think what kind of chain this could be: in fact, it could hardly be called a chain at all; 14s. per hundredweight was much less than a competent workman would be paid in wages alone for making a good ¼-inch chain, and this was just an illustration of one of the difficulties which arose when the purchase of ordinary iron chain was contemplated. The absence of a standard of quality, both in regard to material and in regard to workmanship, left them always in the dark as to what they were really purchasing in the form of welded-iron chains, whereas with weldless-steel chains this difficulty was entirely obviated, there being only one quality and one price.

The discussion was closed, and a hearty vote of thanks was awarded to Mr. Strathern.

[redacted]

THE SOUTH STAFFORDSHIRE AND WARWICKSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,

HELD AT ARBURY HALL, WARWICKSHIRE, JUNE 16TH, 1908.

MR. ALEXANDER SMITH, PRESIDENT, IN THE CHAIR.

The minutes of the last meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. J. C. FORREST, Holly Bank Colliery, Essington.
Mr. R. HOOD HAGGIE, Queen Victoria Street, London, E.C.
Mr. LANGFORD RIDSDALE, Tamworth.

ASSOCIATE MEMBER—

Mr. WILLIAM JOHN HORNER, Director of Kent Collieries, Limited, Tollington Park, London, N.

ASSOCIATE—

Mr. W. D. ROSE, Hamstead Colliery, Great Barr.

Mr. JAMES CUNLIFFE's paper on "Methods of Working the Warwickshire Thick Coal at the Hawkesbury Colliery, Bedworth," was read as follows:—

METHODS OF WORKING THE WARWICKSHIRE THICK COAL AT THE HAWKESBURY COLLIERY, BEDWORTH.

By JAMES CUNLIFFE.

It is the writer's intention to put before the members, as clearly as is possible in a short paper, the methods of working the Warwickshire Thick coal which were tried at the Hawkesbury Colliery from the year 1872 until the closing of the colliery in 1888.

At first there were three coal-pits working, namely, the New Winnings, Speedwell, and Blackbank. A fourth, the Fly pit, was afterwards worked; but, owing to the great trouble from gob-fires which was experienced in the three first-named pits, a new method of working the coal was tried at this pit in the hope of, if possible, either reducing or abolishing the fires. All the pits were shallow ones, and not subject to a heavy crush.

The method of working in use at the Speedwell and Blackbank pits was as follows:—The coal was worked from main hills, both in the Ryder and in the Slate Coal-seams, in the [redacted]

The working of the coal at the New Winning pit was a little different, as it was worked all to the rise from two levels cut out in the Ryder coal. A pillar, 150 feet thick, was left for protection.

Here the coal was worked in the following order, namely:—(1) Slate coal followed by Ell coal; (2) Slate coal followed by Ryder and Two-yard coal; and (3) Two-yard coal followed by Slate, Ell, and Ryder coal.

The first working made good progress, until the Ryder and Two-yard coal came to be opened out. Difficulties then arose, fires broke out, first on the rib-sides and afterwards in the waste; in fact, the writer has seen more than once the full length of the Ryder gob covered with sand.

A most unfortunate fire occurred one week-end in a jig, where the Two-yard coal had been worked first. The fire got hold of the timbers supporting the roof, and burnt all in front of it. There had been indications that something was wrong, as the breaks or cracks in the Bare coal gave off fire-stink. Large lids were placed on top of the props, in order to give as much support to the roof as possible.

All the fires in the coal were found to be in the top part of the Ell coal-seam, yet, curiously, they were named "Ryder fires." From observations at different times it was found that the Ell coal lifted up, making fractures on open places in the spires. By the continual lifting and crushing of the soft part of the Ell coal, small pieces of coal, pyrites, and dirt would get into these fractures, and the ventilating current of air rushing in and out caused a sweating of the coal which in time produced a fire.

The method of dealing with the fire was to fetch out all the spires as far as possible, afterwards filling in the place with sand or flue-dust.

On the opening of the Fly pit, it was determined (as above mentioned) to try a new method of working, with the object of preventing gob-fires. The idea was to work the White ironstone (fig. 1, plate xvi.), for packing purposes, conjointly with the coal.

The coal and ironstone were worked from one main hill driven in the Ryder coal for something like 3,600 feet, with a dip of 1 in 4. The Slate coal was taken up to the bat, and the Three-quarter coal was left to be worked at the same time as the Ell

coal. These were the first and second workings (fig. 2, plate xvi.). The reason for this was that, by taking only the Slate coal up to the bat it packed itself, with the exception of the wastes, which were filled with clod brought from the White ironstone-working; it allowed all the Ell coal to be taken out, the spires making some very good coal. There was nothing left in these two gobs that could take fire under any circumstances.

As the Ryder and Two-yard coal-seams were the most in need of packing, special attention was given to this point, because the better was the packing the better was the coal. This method of packing provided good roads, and was also the means of saving much timber.

The distances between the coal-faces varied: sometimes there would be a short jig between the Ell and Ryder coals, as also between the Slate and Ell coals, but the distance between the Ryder and Two-yard coals was kept to about 30 feet from face to face.

The length of ironstone-face working depended upon the amount of clod required, as there was no market for the ironstone; but, notwithstanding this, it was better to work a small area of it if by so doing the occurrence of fires was prevented; for it must be remembered that when a fire breaks out, steps must be taken forthwith to combat it, without counting the cost. Fig. 3 (plate xvi.) shows how the working-faces followed each other, and the working of the ironstone-face in advance

[redacted]

the whole of the coal to be got out, with the exception of the Bare coal, which was not worked.

The manager of the colliery (the late Mr. Joseph Cunliffe, of Bedworth) received congratulations from many mining experts on his success in working the Warwickshire coal.

In conclusion, the writer, after his experience, would in no case advise the working of the Two-yard coal first. Where there is a good thickness of strata between the Ell and Ryder coals, it might make all the difference; but where the coals are together, as at Hawkesbury colliery, the bottom coal should be worked first.

The PRESIDENT (Mr. Alexander Smith) said that the question of the methods of working the Warwickshire Thick Coal at great depths was one that had been much discussed and ventilated recently. The difficulties from gob-fires were intensified where the seams came together and were flat. In the districts of the coal-field where the seams dipped and had a good parting between them, the coal-getting was a very different matter, and thev had comparative freedom from fire.

A year or two back, a committee had been appointed to consider the whole question and to place on record the various methods of working the Thick coal which had been adopted in the neighbouring coal-field of South Staffordshire; but, owing to lack of support, nothing satisfactory had been accomplished.

Some time back he had tried to procure a paper from a very experienced authority, Mr. Joseph Cunliffe (now deceased), who was the manager of the Hawkesbury colliery, where the Thick coal had been very successfully worked. The paper now communicated was by that gentleman's son.

Mr. J. T. BROWNE (Newdigate Colliery) said he thought that in the case described by Mr. Cunliffe, they had everything in their favour: shallow workings only about 300 feet deep, and a favourable dip of 1 in 4. It was where the seams were flat and at a depth of, say, 1,800 feet, such as they had at Newdigate colliery, that the difficulties became multiplied. He welcomed any contribution on the subject: for, although not always able to follow it in practice, one often learned thereby what to avoid.

Mr. F. H. Briggs (Charity Colliery, Bedworth) confirmed what had been said by the previous speaker, and added that his experience had been that careful packing was required; and to pack as thoroughly as was necessary, almost as much packing would have to be sent down the pit as the amount of coal drawn. He had found that the best way to contend with gob-fires was by good packing and careful watching.

The President proposed a vote of thanks to Mr. J. Cunliffe, which was seconded by Mr. F. A. Grayston, who observed that Mr. Cunliffe had evidently arrived at the same conclusions as Mr. Thomas Smith, who 40 years previously had found out that it was better to work the bottom seams first.

The further discussion of the paper was postponed.

At the close of the meeting, the members were conducted over the fine rooms and gardens of Arbury Hall, and were afterwards kindly entertained to luncheon by Mr. Frank Newdigate-Newdegate.

During the afternoon the members were driven to the Newdigate Colliery, and the Clara pits of the Griff Colliery Company, Limited, where they inspected the surface-plants, and at the latter place were entertained to tea by Mr. E. F. Melly.

[redacted]

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,
HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
MAY 12TH, 1908.

MR. JOHN ASHWORTH, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. ROBERT ARTHUR FORT, Mine Surveyor, Moss Hall Coal Company, Limited, Platt Bridge, near Wigan.

Mr. F. LLEWELLIN JACOB, Mining Engineer, Ferndale Colliery, Ferndale, Glamorganshire.

Mr. JOSEPH DICKINSON read the following paper on "Deviation of Bore-holes":—

DEVIATION OF BORE-HOLES.

By JOSEPH DICKINSON, F.G.S.

It is fairly well known that the usefulness of bore-holes in searching for minerals or water, tapping water or gas, and ventilating workings, is occasionally thwarted or rendered less helpful by deviation from the intended direction. Appliances have been invented with partial success for ascertaining the line of deviation, but something of a more practical nature is required; and as the want is becoming more apparent, improvement is likely to follow.

The idea of preparing these few notes on the subject was suggested by reading the careful description of a recent deep boring at Barlow, near Selby, which had proved the existence of coal about a dozen miles east of the present collieries in the Yorkshire coal-field.*

This bore-hole was 18 inches in diameter at the top, and diminished to a few inches at a depth of 2,371 feet. It took fully two years to bore, delays being occasioned by want of water and by serious deviations of the hole from the perpendicular, [redacted]

x., vol. xxxiv.), and is said to have represented the opinion of the person who had charge of the boring. This opinion seems also to have been accepted by the several eminent mining engineers and geologists who took part in the discussion on the paper, and being thus authoritatively introduced it may be left unquestioned; indeed, under such circumstances, it seems desirable to add that the following observations are not intruded as controversial discussion, but as a distinct expression, lest the introduction on such high authority may be misconstrued into an axiom applicable generally to bore-holes in inclined strata.

Premising that fissured strata may divert the course of a bore-hole into almost any direction, yet ordinarily, with regular dip, force in boring seems likely to operate otherwise than when acting on bodies moving in fluids or on slopes. In a plumb bore-hole in inclined strata, the boring-cutter comes first on the rise of the bedding; thus—the rise-side of the cutter takes the weight, allows the dip-side to sink, the boring-rod above follows, bending to the dip-side with the cutter below thrusting to the rise; and, as a natural consequence, the bore-hole follows the cutter towards the rise.

As a practical illustration supporting this theory, the writer may mention that sixty years ago, having occasion to sink a second shaft to a seam of coal found previously by boring and proved from a trial shaft, the second shaft was begun with the bore-hole in the centre, in the hope that it would take the water, which it did for a time. The strata had a moderate dip, and the shaft was perpendicular. As the depth of the shaft increased, the bore-hole diverged to the rise-side, and there passing out was ultimately found in the coal-working some yards away on the rise-side. Therefore, whatever definite information may hereafter be obtained as to the direction of the bore-hole at Barlow, deviation to the dip cannot be accepted as an axiom applicable generally to bore-holes in inclined strata.

Without going into details, which are well worth perusal, it may be added that the Barlow boring was by the new Calyx system, in which a rotary cylindrical steel-cutter is used for soft strata and another cutter, with triangular notches and chilled shot, for hard rock, along with combinations for regulating pressure and improving observation of the small outcome borings. The other bore-hole, where the shaft proved the deviation to the

rise, was bored with an ordinary chisel-cutter, spring-pole, and hand-turning.

Whether deviation of direction in either bore-hole was influenced by the system of boring is not noticed: nor are the positions of the Red Sandstone and Coal Measures in the geological series. Each of these items is an important but distinct factor; but what the writer has at present in view is merely to draw attention to the direction most likely to be taken by bore-holes in inclined strata.

Mr. HENRY BRAMALL (Pendlebury) said that he had much pleasure in moving a vote of thanks to Mr. Dickinson for his interesting paper. As to the theory now put forward by that gentleman respecting deviation in bore-holes, he thought that there was a good deal in it. His own view was that the tendency would be for the bore-hole to deviate towards the rise on the tool coming upon a hard bed in the strata.

Col. GEORGE H. HOLLINGWORTH (Manchester), in seconding the motion, said that he had quite recently come across a concrete example of the truth of the argument put forward by Mr. Dickinson. He had consulted one of the most experienced borers as to the probable direction of a deviation, who had stated that in his experience deviation not caused by a fault, or an obstruction in the bore-hole, took the direction of the rise of the measures. He was glad to have this opinion confirmed by [redacted]

the boring cores over a considerable depth. He had had a similar case where the bore had gone a long distance in ground of the same nature, and that pointed to its following the dip. But the expectation as to this bore was that it went to the rise, and Mr. Dickinson had given them particulars of a confirmatory example.

Mr. William Ollerenshaw (Denton) said he thought that the deviation of bore-holes depended very much on the character of the strata in which the bore-hole was driven. He had had an experience of a bore-hole which, about 90 feet from the surface, had deviated about 7½ feet to the dip. Most mining men were aware that there were sometimes ironstone-nodules present in a bore-hole, which would deflect it to the weaker side.

Mr. A. E. Millward read the following paper on "Sinking and Tubbing a Well 15 feet in diameter, and Boring Two Holes 44 inches in diameter, through Gravel, Running-sand, Boulder-clay, and other Measures, at Altham Bridge Pumping-station, near Accrington":—

SINKING AND TUBBING A WELL 15 FEET IN DIAMETER, AND BORING TWO HOLES 44 INCHES IN DIAMETER, THROUGH GRAVEL, RUNNING-SAND, BOULDER-CLAY, AND OTHER MEASURES, AT ALTHAM BRIDGE PUMPING-STATION, NEAR ACCRINGTON.

By A. E. MILLWARD.

Introduction.—In the spring of 1906, the Accrington and District Gas and Water Board obtained by Act of Parliament powers to make new water-works at Altham. For some years the consumption of water had been periodically restricted throughout the district supplied, and upon two occasions (in 1904 and 1905) the reservoirs had only contained 15 and 12 days' supply respectively, owing to the increased requirements of a growing population and the exceptional drought of the previous two or three years. The whole of the water-supply, up to this period, was obtained from the gathering-ground of the outlying hills, but the supply from that source could not be increased.

The neighbouring township of Altham gave positive indications of a vast supply of water, continuous at all seasons of [redacted]

these heavy feeders came from a compact bed of sandstone, lying 90 feet beneath the surface, and 30 feet below the position of the Arley Mine, which had been worked out in this neighbourhood many years before.

The Altham pumping-station lies nearly at the bottom of an extensive synclinal fold, the edges of the porous rocks of which, outcropping north and south, rapidly absorb the rainfall; the overflow, when the water is not drawn upon, gravitates into the river Calder.

It was decided to sink a well 15 feet in diameter into the "Blue Clay," and tub it with cast-iron plates, and then to bore two holes to the bottom of the water-bearing rock, a depth of nearly 180 feet from the surface. As will be seen by the section (fig. 1, plate xvii.), the ground sunk and bored through consists of a series of running-sand, gravel, clay, and boulders.

For winding out the sinking-stuff, a temporary headgear and a pair of engines, with cylinders 9 inches in diameter, were supported on pitchpine baulks, carried upon brick cross-pillars, so as to enable the tubbing to be raised a little above the original level of the surface. The baulks were so placed as to allow the guide-tubes of the bore-holes to be centred from them by lines hanging down the sides of the baulks. The well was centred by placing, before the circle was struck, two points on each of the four sides, from which the true centre could be checked at any time, and which was transferred to a cross-beam bounding the movement of the banking-wagon, when this was fixed.

The Sinking.—The ground was excavated to a diameter of 18 feet, and the first 5¾ feet, consisting mostly of loamy sand, was readily got out. At a depth of 8 feet, water was met with in the sump-hole leading in the centre of the shaft. At this point the sides were supported, from the top downward, with skeleton rings and battens. The rings of wrought-iron were 3 inches deep and 1⅛ inches thick, there being eight segments to the circle, connected together by overlapping joints, with five holes in each end for regulating to the exact size required. These were placed every 3 feet apart. The battens were 1½ inches thick and 8 inches broad, and usually overlapped vertically by 8 inches. These iron rings are, as a rule, only 1 inch thick, but, in this case, the greater thickness was chosen

under the expectation of some heavy work in driving forward the battens at the back of the rings, which expectation was fully verified, and thus rendered a stiff ring very necessary.

The first of these rings was suspended by hangers from eight planks, 3 inches thick and 10 inches broad, placed, as shown in fig. 3 (plate xvii.), upon the original surface, the first four being sunk in the ground at four equidistant points, to the extent of their own thickness tangential to the circle of the ground got out. The other four planks lay evenly upon the first four, and the ground between them, tangential to points of the same circle, midway between the others. Very little weight could come upon the planks when the other supports were fixed tightly. The battens were forced well against the sides of the pit by wedges of hard wood, 2 or 3 inches thick at the head, driven between them and the wrought-iron rings. Where the ground was of a loose and running nature, it was found necessary at periods to play upon the top of the wedges to keep the battens perfectly tight.

After the ground had been cleared out to a depth of 8 feet, a pulsometer pump was put in to deal with the water that rapidly drained into the pit through the sandy ground. The quantity of water increased as the sinking proceeded, and before long some of the beds of sand commenced to work like barm, and in other cases squirted through the joints of the battens. This was quickly stopped by caulking those joints with hemp; and it was very seldom that the water or sand broke out a [redacted]

the well had been reached, even what had been the running-ground, and a source of great trouble during sinking operations, stood during the withdrawal of the battens, and did not cause the slightest inconvenience; but here and there, where the sand had been purest, there were hollow places extending several feet horizontally. These were puddled up with loamy soil, and well rammed afterwards.

This method of work proceeded without hindrance until the Blue Clay was reached, where a water-garland was put in at a depth of 23¾ feet, to enable the lower work to be put in dry. This ring was 9 inches broad, with sheet-iron shrouding 6 inches high, and was at first supported on flat wrought-iron pins 3 feet long, driven into the clay; but, owing to the water rising, through the failure of the pump, and the clay being of rather a soluble nature, the ring became damaged on the weaker side of the shaft, and afterwards was supported by iron hangers suspended from the lowest iron skeleton ring.

The bed of the tubbing-curb was prepared on a foundation of concrete, 3 feet thick vertically and 3 feet broad, widening out a little further at the bottom, and brought up at the back of the position of the curb, being made level with the top of the same and reinforced at this point, with one of the wrought-iron skeleton rings bedded in the concrete. Before the tubbing was built, a lining of brickwork, 9 inches thick, set in cement-mortar, was put in to form a solid backing; and to enable the concrete to set beneath and around the position of the wedging-curb, so that the latter might be effectually wedged without delay in the setting of the concrete, the bottom of the brickwork was set back, as shown in fig. 2 (plate xvii.), and gradually brought into the required line, leaving here a clear space of 2 inches between the brickwork and the position of the flanges of the tubbing-plates. When the brickwork had been brought up to within two courses of the garland-ring, four short lengths of 2-inch wrought-iron pipes were placed horizontally at equidistant points in the brickwork; and afterwards vertical pipes were connected to them and carried upwards at the back of the brickwork, which pipes were here provided with ¾-inch holes, 3 inches apart, in order to drain the ground and thus remove any pressure at the back until the cement was set. The brickwork was backed with small broken stone well rammed.

This operation having been finished, the tubbing-curb was put together on the bed prepared for it; sheeting of yellow-pine, $\frac{3}{4}$-inch thick, and cut to the section of the curb, was placed between each segment; and "glutting," 2 inches thick, also of yellow-pine, with the grain of the wood placed vertically, just filled up the space at the back of the curb. Wedging was then commenced, and the curb was wedged tight in five shifts, six men working in each shift. In the process of wedging, at first yellow-pine wedges were employed and continued to be used so long as they could be got in without breaking; and these were followed by pitchpine wedges, until even the steel chisel could not be made to enter. Before placing the first ring of tubbing-plates, it was necessary to brick up with a single brick in each case from the walling, set further back at this point, for the purpose before mentioned, to within 2 inches of the position of each pair of vertical flanges, so as to enable this ring of plates to be securely and truly fixed in the usual manner by spear-wedges driven into position with the utmost force. These wedges, applied in pairs, and "wedded" as shown in fig. 2 (plate xvii.), were of pitchpine, 2 feet long, 4 inches broad, and from $1\frac{1}{2}$ to 2 inches thick at the head.

Between all the joints, both vertical and horizontal, yellow-pine sheathing, $\frac{3}{8}$ inch thick, was placed, the grain of the wood in each case running in the direction of the subsequent wedging. The whole of the plates were thus built up, each ring made [redacted]

top three rings of plates and the curb was left until the last, so as to allow of the concrete setting.

The wedging began at the bottom, and the vertical joints were almost completed before the horizontal joints were started—a practice not always observed—but the object aimed at in this method was the prevention of the lifting of the plates, by first forcing them well against the sides and thus avoiding the thickening of the lower horizontal joints at the expense of the upper horizontal joints; otherwise, it might have been difficult to get a chisel in and to make the joint watertight, added to which there would have been serious risk of fracture of the plates.

As a rule, the tubbing was twice wedged with yellow-pine wedges and then twice wedged with pitchpine wedges. By way of comparison, pitchpine wedging alone was tried in one or two places, no wedges of yellow-pine being used at all at those points; but, in such places, a greater difficulty was experienced in finally stopping the percolation of water through the joints.

Almost the whole of the wedges used were made from machine-sawn pieces, pointed with a clogger's knife. The ripped and entirely hand-shaped wedge is undoubtedly the better of the two for driving, but is not considered worth the extra expense, the cost of making them being fully three times that of the sawn wedge; and there is very little difference, if any, between the waste of timber arising from extra breakages of sawn wedges, and that incurred in the operation of ripping when making the other kind. It may be pointed out that every care was taken to use only seasoned timber of the best quality, straight-grained, and free from knots and defects.

In the bottom of the well, cast-iron guide-pipes for the bore-holes, of 4 feet inside diameter, were fixed on the pump-line, their centres being 8 feet apart, and were surrounded with a depth of 4 feet of concrete. The Blue Clay was found to yield a little water, and to meet this, and to enable the concrete to be got into position and to set, without being interfered with by the water, the two cast-iron guide-pipes were connected together at the bottom with a 3-inch pipe, the pump keeping the water down "on the snore" in one of the 4-foot pipes. Several stone-drains were also arranged at the bottom leading to the guide-tubes, so that the water coming from every direction might be successfully dealt with.

The Boring.—Before starting to bore inside the 4-foot in diameter guide-pipes, steel lining-tubes were lowered to the bottom of the hole, and these were kept well driven forward as the boring proceeded through the alluvial drift. These tubes were 44 inches in diameter and $\frac{1}{2}$ inch thick, formed of two plates, each $\frac{1}{4}$ inch thick; and were in lengths of 4 feet, each plate forming a complete ring of itself, being butt-jointed, and placed horizontally quarter-circle on with its companion plate, and overlapping 1 foot vertically for riveting the lengths together.

The American method of boring was adopted, which appears to be the most rapid, and ensures a very true and straight hole. The derrick, built of 2-inch planks, 8 inches broad, was about 60 feet high. The boring-tool first employed consisted of a wrought-iron head, 40 inches in diameter and 9 inches deep, studded with twenty-six cutters attached to a boring-bar, 15 feet long and 5 inches in diameter; the whole weighing about 2 tons, suspended and worked from a manilla rope 10 inches in circumference.

The percussive motion was imparted to the tool by connecting one end of a "walking-beam" to an engine-driven crank, and the other end of the beam to the boring-rope; the intermediate connection of the latter being a strong stirrup and temper-screw, for gradually lowering the tool as it cut its way into the strata, with cross-head attached, and a clamp for gripping the boring-rope. The stirrup was attached to the walking-beam [redacted]

clay and stone at a depth of 39 feet from the boring-stage. By working single shifts of 12 hours a day, the alluvium was passed through on June 26th at a depth of 68½ feet from the same datum-level. The Boulder-clay presented many difficulties. The Arley Mine, which was thought to be too near the outcrop to be workable, was expected to be reached at a depth of 78 feet, but the seam had been worked out; and the shale above, shaken by this operation, bored unevenly and slowly. The first set of steel tubes was driven tightly down to a depth of 88 feet, after which a smaller boring-tool was used, and the bore-hole carried down to a depth of 121 feet before a further set of steel tubes was applied. Then the hole was continued to a depth of 124½ feet, at which depth the top of the water-bearing rock was reached on August 14th, 1907, and the 40-inch steel tubes were driven tightly down into it. On August 19th, 1907, in order to expedite matters, a second shift was started, and on September 4th the black shale at the bottom of the water-bearing rock was found at a depth of 173½ feet, the bore-hole being stopped at a depth of 174 feet.

After thoroughly sludging the hole, 6 hundredweight of cement was lowered in a specially-prepared bag, deposited, and flattened out upon the bottom, to receive the rising-main of the pumps. After this cement had been allowed to set, the water-bearing rock was lined with steel tubes, 36 inches in internal diameter and ⅜-inch thick, formed in the same manner as the others, and perforated with holes ¾ inch in diameter and of 5 inches pitch, so as to allow free entry of the water to the pumps, and yet to prevent detached pieces of rock from falling upon the pipe-column and making difficult the withdrawal of the pumps in case of need.

The second bore-hole was put down and finished in a similar manner.

Engines are being put in at the present time capable of raising 1½ million gallons of water per day under a total head of 440 feet. It is expected that the feeder will average 1 million gallons per day if exhausted to a minimum, which event, however, cannot occur with certainly less than a year's continual pumping at the maximum speed of the engines employed.

On the motion of Mr. G. B. HARRISON (H.M. Inspector of Mines, Swinton), seconded by the Honorary Secretary (Mr. SYDNEY A. SMITH, Manchester), the thanks of the meeting were accorded to Mr. Millward for his paper.

The PRESIDENT (Mr. John Ashworth) remarked that this was one of those practical papers that the Society was always glad to receive, and he was sure that they would be very pleased to have a discussion upon it.

Mr. A. E. MILLWARD (Accrington), in reply to Mr. Charles Pilkington, said that the thickness of the tubbing-plates was $\frac{3}{8}$ inch; and they had three vertical and three horizontal ribs; he was of opinion that more depended upon the strength of the ribs of tubbing-plates than on the thickness of the plates.

The HONORARY SECRETARY (Mr. Sydney A. Smith, Manchester) said that he would like to ask a question on the following statement in the paper, namely, that "the wedging began at the bottom, and the vertical joints were almost completed before the horizontal joints were started" . . . in order to prevent "the lifting of the plates, by first forcing them well against the sides and thus avoiding the thickening of the lower horizontal joints, etc."* Did that mean that the wedges were put in from the inside, in order to swell out the tubbing to fit the shaft? Would it not have been very much better to have wedged the tubbing outside between it and the strata or side of the shaft, and fix tight the

[redacted]

completed before the horizontal joints were wedged in. He (Mr. Smith) was of opinion that Mr. Millward ought to have wedged the tubbing first of all on the outside, and so fixed it in position that when he came to wedge inside to make the joints water-tight it would not have disturbed the tubbing.

Mr. A. E. Millward said that the pressure in the process of wedging was exceedingly great. An acquaintance of his had said: "We had such a job when we came to wedge our upper horizontal joints; we could hardly get the chisel in." In his case, not having the holding-down curb sufficiently set and anchored, he could not risk any lifting of the plates. He thought that it was inadvisable to wedge alternately vertical and horizontal joints, and so he had every vertical joint wedged as tightly as possible before proceeding with the horizontal joints.

Mr. Sydney A. Smith said that the point which he wanted to make clear was this:—Mr. Millward had stated that the vertical joints were wedged first of all, the object aimed at being the prevention of the lifting of the plates by first forcing them well against the sides. His (Mr. Smith's) idea was that Mr. Millward ought to have wedged the rings first of all so tight in the shaft—from the back—that the wedging from the inside would only be to make the joints water-tight.

Mr. A. E. Millward did not think that that could be done. He did not think that one could wedge the tubbing by any process at the back without the subsequent wedging moving back the plates. The plates did not stir to any obvious extent when the vertical and horizontal joints were wedged from the inside, and the tubbing was now perfectly water-tight.

In reply to the President, Mr. Millward stated that there was a very good supply of water, and there had been as much as 60,000 gallons an hour flowing about a fortnight after the occurrence of heavy rain-storms. The pumps in the bore-hole were a pair of buckets, 18 inches in diameter, worked by rods. The engines were of a local make, and the pressure of the boilers under steam was 150 pounds per square inch. The water was very free from sand, and a little hard.

Mr. Joseph Dickinson (Pendleton) said that the writer stated that " between all the joints, both vertical and horizontal, yellow-

pine sheathing, $\frac{3}{8}$ inch thick, was placed, the grain of the wood in each case running in the line of the subsequent wedging."* As to the grain of the wood, he had heard some difference of opinion expressed as to what was the best way of placing sheathing between the tubbing. Which grain did the writer mean?

Mr. A. E. Millward said that he meant the vertical grain. He did not think that any other grain would matter, so long as the grain was in such a direction that it would easily cleave and take the wedges. That was the only point to notice, for unless that were done the wedges could not be driven in.

Mr. William Pickstone (Kersal) enquired whether the rainfall very rapidly found its way to the hole.

Mr. A. E. Millward replied, moderately so. Roughly speaking, it took about a fortnight to get through. He had a similar experience when engaged at a neighbouring sinking. In about a fortnight after a continuous rain-storm they would find the water increasing while the pumps were doing their usual work.

Mr. A. E. Millward, in reply to Mr. Dickinson, said that he did not think that workings in the Mountain Mine (900 feet below) would disturb the water, as there were several thick layers of shale that were bound to keep back the water in its native rock. His experience of other workings gave him assurance [redacted]

Mr. Sydney A. Smith asked what was the total area of the gathering-ground from which the water flowed to the bore-hole.

Mr. A. E. Millward replied that, speaking roughly, it would not be more than 5 or 6 square miles; and on either side there were hills that must bring down water, and when the ground was well drained a great quantity of this must also be absorbed. There was a large layer of sandstone rock that would rapidly take the whole of the overflow of water; he simply took the ground over the rocks which could be measured in many ways.

THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, JUNE 20TH, 1908.

MR. JOHN H. MERIVALE, PRESIDENT, IN THE CHAIR.

The ACTING SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on May 30th and that day.

The PRESIDENT (Mr. John H. Merivale) said that the principal matter in connection with the proceedings of the Council was the appointment of an Honorary Secretary, Mr. T. E. Forster having kindly undertaken that office. He was sure that this would be very gratifying to the members, and they would feel that they owed a debt of gratitude to that gentleman. Whether he [redacted]

should take place during the presidency of Mr. Merivale. The scheme of hanging the portraits of all the past-presidents in the Lecture Theatre was promulgated some six years ago, but it was due to Mr. Merivale that it had been completed, and they all felt very much indebted to him.

The PRESIDENT said that, in the name of the Institute, he had very great pleasure in accepting the portraits. He had certainly taken an interest in the matter, but so had others. Mr. J. G. Weeks, he remembered, was in the chair when the movement was initiated, and Mr. Thomas Douglas presided when it was confirmed. The matter had, however, hung fire until Mr. T. E. Forster came forward and presented the portraits of his progenitors: his grandfather and father; and he was very pleased to see that in the course of two years or more there was a strong probability of Mr. Forster's own portrait gracing the walls. It would be very interesting to see thereon the portraits of father, son, and grandson. He thought that Messrs. James Bacon & Sons were to be congratulated on the excellent and artistic way in which the work had been carried out, and the members cordially thanked Mr. Forster for undertaking in the name of the donors to present the portraits to the Institute.

Mr. THOMAS DOUGLAS (Darlington) said that they would all feel that a pleasant duty had been performed that day. It was gratifying for many reasons. They did not live for ever, and it was pleasant to think that the men who had presided over the Institute from its earliest period should have an opportunity of being seen in future years. Photography was now such an excellent institution and so valuable that they ought not to be without photographs of those friends and members of the Institute. It was pleasant by such means to revive one's recollection of them after they had passed away. The possession of the portraits he considered to be a valuable acquisition to the Institute.

Mr. A. L. STEAVENSON (Durham) supported what had been said by Mr. Douglas, who was one of the original members of the Institute. His own connection dated from 1855, and he believed that they had both done their duty to the Institute. They had attended as many meetings and written as many papers as most people, and had always taken a great interest in the proceedings. He

thought that interest had been fully returned, for he always found that there was more benefit to the writer of a paper than to those who sat and listened to it. In writing a paper they divided the subject into heads and then filled it up with what information they could collect from all kinds of sources. His first paper, written in 1859, and read in 1860, was "On the Manufacture of Coke in the Newcastle and Durham District."* It certainly did him a great deal of good, and he believed that it was the means of obtaining for him the position which he had held ever since. If he spoke well of the Institute, the benefit was mutual and very great. He would point out to the younger members that there was still a number of vacant places in their portrait gallery for future presidents, and he hoped that they would strive to do their best to fill them. The late Mr. Nicholas Wood was president for eleven years after he (Mr. Steavenson) became a member. There were now very few of the original members, and he believed that only six remained who were members when he joined the Institute. It therefore gave him great pleasure to be able to take part in that day's proceedings.

Mr. J. G. Weeks (Bedlington) also endorsed the remarks made by the previous speakers, and said that he was glad to see the lecture theatre, which was more or less identified with his term of office, furnished with the portraits. He believed that only five of the original members now remained, namely, Mr. [redacted]

Mr. George Victor Septimus Dunn, Mineralogist and Consulting Mining Engineer, 7, St. James' Buildings, William Street, Melbourne, Victoria, Australia.

Mr. Alfred Hewlett, Managing Director of The Cossall Colliery Company, Limited, Cossall, near Nottingham.

Mr. Joseph Parker Hindmarsh, Inspector of Collieries, Corrimal, South Coast, New South Wales, Australia.

Mr. Kingsley Hopwood, Mining, Mechanical and Electrical Engineer, Beech Leigh, Buckley, Chester.

Mr. Daniel Hotchkis, Colliery Manager, Mount Kembla Colliery, Wollongong, New South Wales, Australia.

Mr. Albert Jennings, Works Manager, 12, Grainger Street, Darlington.

Mr. Edward Morrison, Colliery Manager, 51, Pica Cottages, Distington, S.O., Cumberland.

Mr. William Frederick Price, Engineer, A Floor, Milburn House, Dean Street, Newcastle-upon-Tyne.

Mr. David Thomas, Civil and Mining Engineer, Quay Street, Ammanford, S.O., Carmarthenshire.

Mr. Charles Edward Turner, Mining Engineer, Mina Campanario, Valverde del Camuio, Provincia de Huelva, Spain.

Mr. Foster Williams, Mining Engineer, Miniera di Libiola, Sestri Levante, Italy.

Associate Member—

Mr. George Ralph Gibson, Tyne Saw Mills, Hexham.

Associates—

Mr. Hugh Clarkson Annett, Mining Student, Widdrington, Acklington, S.O., Northumberland.

Mr. Percy Lindsay Lascelles, Colliery Surveyor, Coundon, Bishop Auckland.

Students—

Mr. Norman Elsdale Barber, Mining Student, Seghill Colliery, Seghill, Dudley, S.O., Northumberland.

Mr. Stanley Walton Brown, Mining Student, Seghill Colliery, Seghill, Dudley, S.O., Northumberland.

DISCUSSION OF MR. W. M. EGGLESTONE'S PAPER ON "THE OCCURRENCE AND COMMERCIAL USES OF FLUORSPAR."*

Mr. Benjamin L. Bradley (Grindleford, Derbyshire) wrote submitting three pieces of Derbyshire fluorspar from the Moorfurlong mine, which were good average specimens. The fluorspar would be found of rather a softer nature than that obtained from Weardale.

Mr. David Burns (Carlisle) wrote that Mr. Egglestone had

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 236.

brought forward a subject of great interest. If ever they were to know much of the contents of the metalliferous lodes of the Dales, at any rate in the form in which they now found them, it must be by a careful study of the succession of crystals, and an explanation from chemists of the conditions necessary for each succeeding formation. To get full value of the arrangement of the crystals in a specimen, it should be carefully observed before it was broken from its original seat. Mr. Egglestone had referred to the common phenomenon of small crystals coating one side of a large crystal, whereas another side might be destitute of coating. If the specimen before being disturbed had the coated faces of the crystals on the upper side, and there only, they would be justified in assuming that this secondary mineral had been precipitated either as dust from a gaseous envelope, or in some other form from a liquid one. Then, if covering the western faces only, say, the secondary mineral had been brought by a strong current from the west. All these important data were lost when the specimen had been broken off without due notice having been taken and recorded. He (Mr. Burns) had in his possession a specimen which he had obtained many years ago in West Allendale, which he believed came from the Carshield mine, but of this he was not quite sure. The specimen showed the following stages:—

(1) Fluorspar had been deposited with a free surface, allowing of the formation of perfect crystals; (2) on these crystals [redacted]

minerals; and he had, when preparing his paper, made enquiries of miners, and had been informed that in the cavities or vughs where fluorspar in crystals was generally found, the upper faces only were those invested with secondary minerals; but this point required further investigation and confirmation. Considering that water-vapour never condensed except upon a solid substance; and that all condensation of water-vapour in the air, whether rain, mist, fog, cloud, or snow, took place on a nucleus of dust,* it might be asked whether dust-motes had anything to do with this process so far as scattered crystals were concerned. If a dust-mote was necessary to the formation of a drop of rain, would dust-motes settling upon the clean upper surface of a fluorspar cube in a cavity induce the formation of investing crystals?

Hand-specimens of fluorspar, showing crystals invested apparently on the sides, might, when in their natural home in the cavity in the mine, show that the invested sides were, in nature, uppermost. Fluorspar had evidently been, in many metalliferous veins, the early mineral; and in many mines pseudomorphs or isomorphs showed that the original fluorspar, after being overlain or covered with other minerals, had been dissolved out, leaving an empty mould. These hollow imprints of fluorspar were common in Boltsburn mine, Weardale, one of them, in the possession of the writer, having the inside of the mould studded over with quite a number of pea-sized crystals of zinc-blende, deposited, of course, after the fluorspar had disappeared.

The writer had also in his possession an interesting specimen from the Sedling mine, Weardale: a solid angle of fluorspar, broken off in the mine, and having edges extending to some 4 inches. This solid angle had been completely covered with quartz, ¼ inch thick. This quartz-cap had, in like manner, been completely covered with beautiful bluish-purple crystals, with sides measuring as much as ½ inch, and the shape of the original solid angle of fluorspar was fairly well maintained. This third deposit formed a handsome and instructive specimen of crystalline fluorspar.

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* *The Realm of Nature*, by Hugh Robert Mill, 1892, page 113.

DISCUSSION OF MR. H. W. G. HALBAUM'S PAPER ON "CAST-IRON TUBBING: WHAT IS ITS RATIONAL FORMULA?"*

Mr. H. W. G. Halbaum (Horden) wrote that as Prof. Louis and Dr. Morrow had not seen fit to withdraw, modify, or justify certain remarks they had made in the previous discussion of the paper, he felt it necessary to examine those utterances a little more fully. That necessity arose from the fact that the scholarly status and collegiate environment of those critics might invest their strictures with a glamour which many might mistake for logic and light.

First, with regard to the place of corrosion, it was only necessary to say that if Prof. Louis could state the case more definitely, he (Mr. Halbaum) would be pleased to see him succeed in doing so.

Secondly, Prof. Louis had stated that he (Mr. Halbaum) had "quietly disregarded the main difficulty of the whole problem, inasmuch as he had treated a ring of tubbing as a plain cylinder, which was precisely what it was not."† With regard to the office of the ribs and flanges, the author had devoted nine pages of his paper to the careful consideration of this question;‡ whilst with regard to the segmental structure, that, also, was fully considered in Appendix III.,§ and illustrated by four figures on plate xxiii. If Prof. Louis had recognized the simple fact that segments of tubbing were merely frustums

[redacted]

Beyond showing, however, that the case of the tubbing-ring really resolved itself into the "simple" case of the plain cylinder, he (Mr. Halbaum) had hardly troubled himself in the way which Prof. Louis described. The main object of the paper had been to rescue the case of the cylinder from the sciolistic and contradictory formulæ under which certain men—Prof. Louis himself, the co-sponsor for the now abandoned formula of Prof. Galloway, amongst them—had for years endeavoured to obscure it. The formula, for instance, for which Prof. Louis himself was jointly responsible, proceeded on the absurd assumption that the area of the outside pressure was less than the area of the inside surface of the tubbing: that cast-iron doubly thick was more than doubly strong; that corrosion was a myth of the imagination; and that the safe stress might always be taken at one-third of the ultimate crushing-stress of the metal. Prof. Louis had since advocated factors of safety five times as large, and yet he talked of the "simple case of the plain cylinder" being "solved long ago."

But Prof. Louis had enlisted the services of Dr. Morrow in the solution of the tubbing problem, and attention might be called to the positions which the latter had chosen to take up. The first point attempted by Dr. Morrow was to frame a great indictment of the logarithmic formula propounded by him (Mr. Halbaum). That attack was remarkable for several peculiarities. First, Dr. Morrow's attack was unnecessary, since nothing would be gained by it, even if it succeeded. Both Dr. Morrow and himself had stated an "accurate" rule, and an approximate and easier rule for practical use. The relative results (or thicknesses of tubbing stated as percentages of the inside radius) of each rule were set forth in the annexed table.

It was evident from the above table that the differences of the rules, within the limits of the tubbing case, at any rate, were practically *nil*, so that in the extremest tubbing case, Dr. Morrow's "accurate" formula, so-called, would give a thickness about one-quarter of one per cent. less than the thickness directed by the hyperbolic rule. In all other cases, the difference would be less even than that small amount—an amount which in practice would hardly be considered measurable, and

which, in the ordinary tubbing case, would not be measurable. For example, in a shaft 16 feet in diameter, having tubbing of the unheard-of thickness of 9 inches, by the hyperbolic formula, Dr. Morrow's theoretical formula would give the thickness one-hundredth of an inch less. Hence, the first point would be perfectly clear, namely, that Dr. Morrow's contentions could have no tangible result, even if members accepted them. It seemed to the writer, therefore, that it was a pure case of "Much Ado about Nothing."

TABLE SHOWING RELATIVE THICKNESSES OF TUBBING (IN PERCENTAGE OF INSIDE RADIUS) REQUIRED FOR PRESSURE ONLY.

By Halbaum's Hyperbolic Rule.	By Halbaum's Practical Rule.	By Dr. Morrow's "Accurate" Rule.	By Dr. Morrow's Practical Rule.
1·00	1·00	1·00	1·00
2·00	2·00	2 00	2·00
3·00	3·01	3·00	3·00
4·00	4·01	4·00	4·00
5·00	5·02	5·00	5·00
6·00	6·03	6·00	5·99
7·00	7·03	6·99	6·99
8·00	8·04	7·99	7·98
9·00	9·05	8·99	8·97
10·00	10·06	9·98	9·96
11·00	11·07	10·98	10·95
12·00	12·07	11·97	11·93
And so on up till	$p = \frac{1}{4}f$, at which p	oint the relative thi	cknesses become:
43	41⅔	41½	40

Secondly, it could easily be proved that Dr. Morrow's arguments were inconsistent and self-destructive. After speaking [redacted]

"accurate" rule would go by the board, a fact which could be verified by comparing columns 1 and 3 of the above table.

With regard to Dr. Morrow's practical formula, the use of which he (Dr. Morrow) was pleased to recommend "under all circumstances," the relative results of that rule were set forth in column 4 of the above table.

Dr. Morrow had stated that: "It was, perhaps, worth while to point out that a formula might give excellent results when used in connection with internal-pressure problems, and yet be at fault in the case of external pressures. It must always be borne in mind that, even for cylinders under internal pressure, the only reason why the logarithmic formula might be used was because it gave results which agreed more or less closely with the more accurate theory."* The "more accurate theory" alluded to thus was, of course, the Aldis approximate theory. But Dr. Morrow went on to show, in his way, how different it was in the case of external pressure, and said "how wrong it was to take a formula obtained for cylinders under internal pressure and to endeavour to amend it to suit the external-pressure problem."† Yet that was precisely what Dr. Morrow himself had done, the proof being as follows:—

Prof. Jamieson gave the following rule for cylinders under internal pressure:—‡

$$\operatorname{Log}_e \frac{R}{r} = \frac{p}{f} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

But since many men prefer the direct arithmetical method, Prof. Jamieson remarks that:

$$\operatorname{Log}_e \frac{R}{r} = \frac{2(R-r)}{R+r} \text{ very nearly} \quad . \quad . \quad . \quad (2)$$

provided that $\frac{R}{r}$ was not greater than 2.§ Substituting that value of $\frac{R}{r}$ in equation (1) above, they got for the thickness:

$$t = \frac{pr}{f - \frac{p}{2}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

* *Trans. Inst. M. E.*, 1908, vol. xxxv., pages 68-69.

† *Ibid.*, pages 70-71.

‡ *Text-book of Applied Mechanics*, by Prof. Andrew Jamieson, second edition, 1900, vol. ii., page 248.

§ *Ibid.*

which was Jamieson's practical formula for cylinders under internal pressure. But if by r they understood the external instead of the internal radius, and if by f they understood the safe compressive instead of the safe tensile stress, Jamieson's formula for the internal-pressure case became Dr. Morrow's rule for the external-pressure problem. That was the Doctor's formula (11); it was "recommended under all circumstances"; and it was simply Jamieson's formula for cylinders internally pressed, "amended so as to apply to the external-pressure problem" by Dr. Morrow himself. His "recommended" formula for external pressure "under all circumstances" was merely an approximation to Jamieson's approximation to the standard for the internal-pressure problem. The Doctor's condemnation of "approximations" thus applied only to his own formulæ.

But the logarithmic formula propounded by the writer was deduced independently for the external-pressure case. Anyone could prove that by referring to the appendix above-named. The late Mr. M. Walton Brown, in his energetic way, had pressed the writer to get the paper ready for the meeting of The Institution of Mining Engineers, held in London in June, 1907; otherwise, the said appendix would have formed an integral portion of the body of the paper. Its object was to show that the case of the cylinder—so far as that could be understood—was simple enough to be stated without the use of the calculus, no matter whether the cylinder was a continuous ring or a

[redacted]

. . . . was not to be mentioned in connection with short or over-ringed tubes." Precisely; that was what he (Mr. Halbaum) had emphatically urged. But it was surprising that Dr. Morrow should say so, since Dr. Morrow's formula (24) was directly deduced from, and based upon Fairbairn's rule, the difference of properties possessed by cast-iron and wrought-iron being taken into account; whilst the essentially vital difference of environment due to fluctuations of temperature was absolutely overlooked and ignored by him—an oversight which completely deprived the amended formula of any little value it might otherwise have possessed.

Thirdly, in view of Dr. Morrow's inconsistency, it would be advisable to examine his theory. His theory of the office of the ribs and flanges would scarcely be taken seriously by practical men, since, followed to its logical conclusion, it led to the theorem that a structure might be vastly stronger than its weakest part. But Dr. Morrow had fallen into yet another error, opposite in one sense, but similar in another, and an error which all men might not so easily detect. Objecting to the logarithmic rule, he (Dr. Morrow) had remarked: "The strain . . is due to the normal compressive force, as well as to the circumferential stress; and it is only this latter part that can be divided into the stress q to obtain the modulus E."* Dr. Morrow appeared to forget several important considerations, whilst devoting undue attention to trifling matters. He forgot, for instance, (1) that the circumferential stress itself was but the effect of the normal compressive force; (2) that the normal compressive forces on the tubbing afforded mutual lateral support to each other; (3) that this very lateral support was itself the great safeguard against collapse; (4) that his recognition of the "normal compressive force" was absolutely inconsistent with his faith in the great bugbear of collapse of which Prof. Louis and himself were so afraid; (5) that provision against the principal stress of any given kind coincidently provided against all minor stresses of the same kind; (6) that Dr. Morrow himself was committed to the principle now stated, since he had admitted that the stress due to the weight of the tubbing might be neglected, even if it amounted to 5,000 pounds per square inch.† And, finally, Dr. Morrow had quite overlooked the prac-

* *Trans. Inst. M. E.*, 1907, vol. xxxiv., page 111. † *Ibid.*, page 121.

tical proof of his error furnished by the significant fact that the logarithmic formula, leaving those minor stresses out of account, gave results absolutely as safe as his so-called "accurate" formula, which presumably took them into account, since Dr. Morrow approved of it. If Dr. Morrow's objections were worth anything at all, he should be easily able to show a conceivable tubbing case where the hyperbolic rule would fail and where, at the same time, his so-called "accurate" formula would succeed. He (Mr. Halbaum) would be pleased if Dr. Morrow would state such a case, practical or theoretical. The latter had already found it "inadvisable" to reply to his (Mr. Halbaum's) arguments,* and if he would find it equally "inadvisable" to answer the other questions now put, the members no doubt would be able to interpret that attitude as it deserved.

But Dr. Morrow had further remarked that: "the statement . . . . that the circumferential strains depend on the corresponding circumferential stresses only, is also erroneous."† He (Mr. Halbaum) had, as a matter of fact, never made that specific statement, but he was willing to accept it, and to defend it against the Doctor's *ipse dixit*. Dr. Morrow's criticism was either a mere nibbling at trifles, or else a direct attack on Hooke's law of strains. If the former, it was not worth troubling about; if the latter, it was more important, although it was still easily answered. It was probably a fact that during the last few years some men had decried Hooke's law. But the latest researches had shown that attitude to be wrong,

[redacted]

frequently disputed. Certain mechanicians or physicists freely admit (*sic*) it to be incorrect, especially as regards extremely weak deformations. According to a theory in some favour, especially in Germany, that is, the theory of Bach, the law which connects the elastic deformations with the efforts would be an exponential one. Recent experiments, however, by Professors Kohlrausch and Grüneisen, executed under varied and precise conditions on brass, cast-iron, slate, and wrought-iron do not appear to confirm Bach's law. Nothing, in point of fact, authorizes the rejection of the law of Hooke, which presents itself as the most natural and most simple approximation to reality."

The above quotation, coming from a high Continental authority, would doubtless be appreciated by practical men, even if Dr. Morrow should find in it yet another case which it was "inadvisable" that he should answer.

Fourthly, attention might be called to Dr. Morrow's so-called facts. He had attempted to ride down part of his (Mr. Halbaum's) opposition by the statement that Sir John Anderson had not said "anything so absurd" as that surplus material in a structure was a source of weakness.* Of course, every engineer knew that Sir John was referring to redundancy. But the question as to whether or not he made the statement quoted was easily disposed of. Sir John's own words were as under:—

"In designing machines or structures, not only is there a correct form, but it is of the greatest importance that that form should not be departed from unnecessarily. The correct form is that in which every part is proportioned to the straining action to which it is subjected, so that the stress reaches the same maximum limit on every section. If, instead of being thus proportioned, a structure has a surplus of material in some parts, that surplus may not only not strengthen it but may positively weaken it, and may render parts, otherwise of sufficient strength, incapable of sustaining the load for which they have been calculated. Thus, for example, a chain with one link smaller than the others . . . is reduced in strength, not only in proportion to the reduction of section at the weak point, but in a still greater degree. In consequence of the surplus resistance in the other parts, most of the elastic work will be concentrated on the weak link. . . . . Although, strictly speaking, we cannot increase the strength of a structure by securing equality of sectional area, because the strength still remains dependent on the weakest section, yet virtually we increase the strength, by preventing the gradual deterioration of the resistance at one point, and thus diminishing the risk of fracture."†

The above deliverance of Sir John Anderson shattered the entire Morrovian philosophy, and utterly demolished the Doctor's theory that the great sources of strength in the tubbing lay

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 69

† *The Strength of Materials*, by Sir John Anderson, eleventh edition, 1892, pages 155-156.

in the ribs and flanges. Sir John Anderson—an indubitable authority in such matters—therein emphasized the principle that the structure was limited in strength by the weakest section or member. And, hence, he coincidently emphasized the fact that the strength of tubbing for all shafts, deep or otherwise, was limited by the thickness of the shell. At all events, the above quotation proved that Sir John Anderson had really made the statement which Dr. Morrow had pronounced "absurd" and the publication of which the Doctor had denied. There was, however, nothing absurd about Sir John's statement, as it simply affirmed that a surplus resistance in parts of a structure had pretty much the same effect as a surplus temperature in parts—a fact which any engineer with some little knowledge of physics might readily foresee. It had already been pointed out that, in attempting to equate Fairbairn's formula to the tubbing problem, Dr. Morrow had altogether overlooked the factor of differential temperatures. It now appeared that he had further overlooked the factor of differential resistances due to redundancy of material; and not only so, but he had denied that such differential resistances could obtain, and had characterized the principle so clearly explained by Sir John Anderson as absurd.

Fifthly, with regard to Dr. Morrow's actual results in the shape of formulæ, his "plate formula" was Prof. Unwin's rule; but since Dr. Morrow had proposed to apply it in a way that [redacted]

tubbing that was not already sufficiently secure against collapse, and the formula referred to was merely a grotesque result of the collapse-scare recently raised, first in a mild form by Mr. Charles Pilkington and then in the acute form by Prof. Louis and Dr. Morrow. In his (Mr. Halbaum's) opinion, the supposed collapse-risk might be dismissed from their minds as a sheer bogey, so long as the ordinary designs of tubbing were adhered to.

Coming to Dr. Morrow's "ring-formula," its consideration demanded a little more space. First of all, let them clearly recognize that it was a collapse-formula, and a formula which assumed that the collapsing pressure increased as the cube of the thickness. But Prof. W. C. Unwin, whose authority was world-wide, had said:—"In particular it is clear from the experiments that the collapsing pressure does not increase quite so fast as t^3."* However that might be, one thing was perfectly clear, namely, that this collapse-formula was out of joint with the whole problem, seeing that the collapse-idea itself was quite opposed to all practical experience. For example, Mr. Frank Coulson, whose wide experience of such matters was well known, had remarked that: "It seemed to be taken for granted that cast-iron tubbing 2 inches thick would be twice as strong as cast-iron tubbing 1 inch thick, but this did not work out in practice."† He (Mr. Halbaum) would pause a moment to consider why that was so, and he would suggest that tubbing doubly thick was less than doubly strong, for the following reasons:—(1) Because the tubbing cylinder was subject to the law of all cylinders as that was illustrated in the hyperbolic formula for the thickness. (2) Because the redundant material in the thicker tubbing was a greater proportion, and the law laid down by Sir John Anderson was thus more flagrantly violated than in the case of the thinner tubbing. (3) Because (repeating the above in other words) the ordinary tubbing case furnished a problem of crushing forces much more conspicuously than it furnished any real problem of provision against collapse. That was his (Mr. Halbaum's) theory of the case; it agreed altogether with Mr. Coulson's experience that tubbing doubly thick was never found doubly strong; and it explained how futile it was for

* *The Elements of Machine Design*, thirteenth edition, 1892, vol. i., page 84.

† *Trans. Inst. M. E.*, 1908, vol. xxxv., page 48.

Dr. Morrow to come forward with a ring-formula proceeding on the absurd assumption that tubbing doubly thick would be eight times as strong!

The main difficulty of the tubbing problem was not connected with collapse at all. Could Dr. Morrow and Prof. Louis cite half-a-dozen clear cases of collapse from the entire history of mining throughout the world? The main difficulty was not even provision against crushing force: the great case for investigation was that of the corrosive properties and powers of the various mine-waters. As Mr. T. Campbell Futers had manfully said: "the only objection that could be brought against the tubbing of the 'grand old engineers' was not that it was not strong enough, but that they had underestimated the length of time that the tubbing was required to last. He had not heard of a single instance where tubbing had failed owing to a want of sufficient strength to resist the pressure of the hydrostatic head of water."* The element of time alluded to by Mr. Futers was inseparably connected with the corrosive energy of the shaft-water, and therein was the real difficulty of the entire problem. He (Mr. Halbaum) ventured to express the earnest hope that members would not permit their attention to be distracted from that by any side issue. He had furnished a simple formula which would keep that phase of the question constantly before their eyes, and he ventured to state that neither Prof. Louis nor Dr. Morrow had been able to amend it in any single particular.
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CIRCULATION AND HEAT ABSORPTION IN STEAM BOILERS.

BY ARTHUR ROSS.

About twelve to fifteen years ago, a great deal of important work was done and results published upon the rate of heat transference from fire to water in a steam generator. Since that time the subject appears to have been practically dormant, and the interest then aroused has considerably abated. At the time when most of these investigations were made water-tube boilers, the Belleville in particular, were forcing themselves upon the attention of boiler users. Although that question is not now so acute, yet it cannot be denied that the subject of water circulation is still one of great importance, seeing that working pressures are daily increasing, more intense fires are required, and fuel is dearer.

The ideal conditions are represented by the complete absorption in the boiler-water of all heat generated by the fuel. That we can only approximate to such perfection is common knowledge, but the aim of every efficient engineer is to reduce to a minimum the gap between ideal and actual.

One of the most certain helps to this end is to ensure a frequent change of water in contact with the heating surface, or, in other words, a first-class circulation. The reason for this is obvious, when the non-conducting power of water is remembered. The late Lord Kelvin gave the thermal conductivity of iron as 80 times, and copper as 500 times, that of water. The thermal conductivity of iron was given as 3,500 times, and copper as 20,000 times that of air, so that the thermal conductivity of water is over 40 times that of air. For the purpose of comparison, we can take air as equivalent to steam, and consider steam 40 times a worse conductor of heat than water, or 120 times worse than iron. Thus it is clearly advantageous to keep water always in contact with the heating surfaces, as steam taking 40 times as long to absorb the same quantity of heat as iron results in too much heat being stored in the iron tube or plate, with disastrous

results in every instance. Several experimenters have shown that an enormous evaporation per square foot can be obtained with perfect safety, provided that water is always in contact with the metal, from 50 to 100 pounds per square foot per hour having been actually obtained.

Reference was made by the author to Mr. C. W. Williams' work on *The Combustion of Coal and the Prevention of Smoke Chemically and Practically Considered*, published in 1854, the early days of steam navigation, and when the wellknown type of "Scotch" marine boiler was being evolved, but not yet produced. In these early types, large flat surfaces with narrow water-spaces were common, but these boilers continually failed. The failure of these plates was put down to slackness of circulation, resulting in a film of steam adhering to the plates, which prevented the heat from being absorbed quickly enough by the water, overheated and bulged plates being the result. It must be evident that under such circumstances of overheating the heat does not travel through the plate three or five times as fast as before, although the water is boiling, but becomes stored in the plate. One paragraph of this most interesting book is a quotation from Mr. Robert Murray's *Treatise on the Marine Engine*, which states that: "It is a point of the utmost importance that no part of the heating surface of a boiler should be so situated that the steam may not readily rise from it and escape to the surface; since the plate, if left in contact with steam instead of water, becomes unduly heated and [redacted]

Although these figures would not go unquestioned to-day, yet they are instructive as showing that circulation was being considered an important question in those early days of boiler construction.

The Engineer of February 28th, 1908, contains, among other matter important to boiler-users, a leading article on "Maximum Evaporation," in which it is stated that: "The great danger lies in the formation of steam between the water and the plate which remains there. For this reason a rapid circulation should be maintained in order that the steam may be swept away as fast as it is formed."*

Notwithstanding these results, there is still to be overcome the reluctance of water to absorb heat rapidly, resulting in a considerable range of temperatures existing in different parts of even a small vessel; how much greater, therefore, are those differences in a large bulk like a steam boiler, with a maximum temperature many times that of the atmosphere.

It is undoubtedly true that convection currents in fluids assist in the absorption of heat by setting up movements due to the differences in gravity of the warmer particles, but these currents stop when ebullition is general, all movement then being upwards; and these currents, being a natural circulation, support the writer's contention as to the value of circulation, their great drawback being that they cease to operate when boiling is in full swing. Further, convection currents are only above the source of heat, therefore do not operate below the fire-bar level of a Lancashire or similar boiler, so that it is not surprising to find great differences of temperature above and below the furnaces.

Recent experiments made on a dry-back boiler gave the results contained in the annexed table, showing how the temperature of the water at the bottom of the boiler rose hour by hour after fires had been lighted. The steam pressure of the boiler when at work is 160 pounds per square inch, with a temperature of between 360° and 370° Fahr., so that the last readings taken after the boiler had been on load for some hours was about 140° Fahr. colder at the bottom than at the top.

Mr. Rankin Kennedy, to illustrate the poor conductivity of water downward, states that if "water were kept boiling at the

* *The Engineer*, 1908, vol. cv., page 222.

surface, the heat would not penetrate sufficiently to begin melting ice at a depth of 3 inches in less than about two hours."*

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9.0	60	—	3·0	83	15
10·0	60	—	4·0	83	15
11·0	62	—	5·0	83	15
12·0	68	—	6·0	83	15
p.m.			7·0	90	20
1·0	69	--	8·0	92	20
2·0	69	—	9·0	92	25
3·0	70	—	10·0	92	40
4·0	73	10	11·0	97	70
5·0	75	15	12·0	103	105
6·0	76	15	p.m.		
7·0	78	15	1·30	125	140*
8·0	79	15	2·30	166	160
9·0	79	15	3·30	223	160
10·0	79	15	4·30	225	160
11·0	80	15	5·30	224	160
12·0	82	15	6·30	224	160
a.m.			7·30	224	165
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* Boiler on load at 1·50 p.m.

Some interesting experiments were carried out by Mr. Lavington E. Fletcher, chief engineer to the Manchester Steam Users' Association, to which the author would direct the attention of the members.†

That the writer is not singular in emphasizing this subject is shown by the following extracts out of many. In 1874, Prof. Osborne Reynolds communicated a paper to the Literary and Philosophical Society of Manchester, in which he remarks that:

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ing of the plates due to the somewhat large variations of temperature that exist in these drums owing to water in the drum being frequently cooler below the surface than the steam, and causing the bottom of the drum to be colder than the top."*

It may be suggested that so long as the heat is absorbed it does not matter whether it comes from furnace-plate or shell-plate, but when the enormous expansion possible between the extreme temperature is noted, the importance of rapidly distributing the heat all over the boiler will be recognized.

Taking, for instance, an ordinary Lancashire boiler, the heat is excessive at the bridge, probably between 2,500° and 3,000° Fahr., while the temperature of the gases at the last damper may not exceed 500° Fahr., a difference of about 2,500° Fahr., occurring in the length of a single unit. Taking the co-efficient of expansion of steel as 0·00000672 for 1° Fahr., and assuming that the furnaces were at the maximum temperature throughout, as also that the shell was at the minimum temperature throughout, the difference in lineal expansion would be 6·048 inches in a 30-foot boiler. That it is not likely that such severe conditions occur in practice the writer is aware, but they do occur in a modified form in every boiler, explaining the reason for leaky seams and weeping rivets on end-plates. It also emphasizes two other important facts, one, the necessity for rapidly absorbing the intense heat at the furnace and distributing it to colder parts; the other, the importance of preventing any obstruction to the free passage of heat through the plate by accumulations of scale or grease. If these obstructions have accumulated on the plates, then the heat will become stored up in the plate or tube, bringing about the extreme expansion and destruction of the boiler.

Supposing for a moment that the furnace-tube was so secured at the ends that the top and bottom of the tube could be kept at the same length, when heated, the top would have to be compressed and the bottom stretched. Every difference of 1° Fahr. would produce a compressive stress in the top and a tensile stress in the bottom of 93 pounds per square inch.

With regard to the shell, there is not quite the same frequency of movement as in the furnace, as a result of opening the door; but there is no doubt about the magnitude of the stress produced on plates and joints.

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More equal distribution of the heat is becoming more and more recognized as a most important feature, so far as the life and safety of the boiler is concerned: but another valuable detail is that by the effort to distribute the heat more equally, a circulation is set up which induces a more rapid absorption of heat by the water.

The writer does not propose to take more than a cursory survey of some of the classical work done on the subject. Mr. G. A. Hagemann was one of the first to determine accurately the influence of speed on cooling or heat absorption. Other workers as far back as the latter part of the seventeenth century, including Sir Isaac Newton, had preceded him in investigating the question of heat transmission; but so far as the writer has searched for the purpose of this paper, Mr. Hagemann was the first to study with exactness the effect of circulation. Mr. Hagemann's experiments may be divided into three sections, namely:—

(1) To determine the influence which speed of flow had upon transmission when the temperature differences were kept constant; increased flow resulted in greater absorption.

From the figures and curve given by Mr. Hagemann it will be noticed that with no flow at all, the temperature was considerable (due to convection currents), and the whole curve clearly proves that increased flow meant increased absorption, when the available heat was kept constant.

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Another most striking set of experiments were those of Prof. — Ser, of the College of Arts and Manufactures, Paris, his investigations being also to determine the effect of velocity upon heat transmission. The temperature of the heating medium (steam) being kept constant, the effect of different velocities of the water upon the rate of heat transmission is shown in the table and curve contained in his paper, and confirms Mr. Hagemann's results.

Prof. Ser's apparatus was clearly not suitable for experiments with temperatures sufficiently high to produce steam in the circulating water, so that his remark that " the transmission of heat for the same difference of temperature is more than tripled when the liquid is boiling, which is due to the greater speed in the circulation of the heated liquid,"* is only a surmise, and we now known from the later experiments of Mr. G. Halliday that this is not the case, but rather that steam bubbles act as worse conductors of heat than solid water, so reducing efficiency.†

It is unfortunate that further work was not done on the lines laid down by Mr. Halliday, as his apparatus enabled steam to be formed in the circulating water. His experiments demonstrated that the efficiency fell when the steam mixed with the water, and he further proved that there is a critical speed, which, if exceeded, will also lower efficiency, tending to show that the water must be in contact with the source of heat for an appreciable time to absorb its share. After that point of speed is reached, it seems to slip over the surfaces before full heat absorption takes place; but the writer is not certain whether this will apply to boilers where the water returns to the source of heat, although this was no doubt true of Mr. Halliday's apparatus.

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39 pounds per square foot of surface per hour resulted in a temperature difference of about 86° Fahr. higher than when distilled water was used in direct contact with the plate. With a layer $\frac{3}{16}$ inch thick, a 30-pound rate of evaporation caused the external temperature of the plate to rise above 482° Fahr., a difference of about 75° Fahr. as compared with distilled water; and to evaporate 40 pounds, it exceeded 732° Fahr., or 410° Fahr. above the results with distilled water. He also covered the inner space of a boiler with mineral oil, wiping nearly all off and leaving only a thin layer. It was found that the heat in the plate increased considerably, the water side of the plate giving a higher result; and when a moderate evaporation of 35 pounds per square foot per hour was made, all the fusible plugs melted, proving a temperature above 842° Fahr. Further experiments were made with small tin saucepans, which became red-hot at low temperatures when a coating of grease adhered and burnt to the surface. Mr. Hirsch states that:

"He had observed that where an abnormal elevation of temperature was attained in the experiments, black patches, apparently arising from the partial decomposition of fatty matter, adhered to the boiler at the beginning of the trial, not having been completely removed by the cleansing. Wishing to discover if they had any influence on the phenomena of the transmission of heat, he greased a clean tinned saucepan with mineral lubricating oil and heated it without water over a slow fire to decompose the fatty matter. The bottom of the saucepan was found to be covered with a black coating to which water would not adhere. The saucepan was then filled with water, and heated over the furnace. After boiling a minute one part at the bottom of the saucepan was seen to become red-hot, and the incandescence soon

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bottom when covered with a thin crust of salt, is smeared with cold mineral oil. The smallest quantity of linseed oil at the bottom of the saucepan immediately produced overheating even with the low temperature of evaporation of 20 to 24 pounds. Spirits of turpentine and oil of turpentine did not produce overheating unless mixed with a small quantity of linseed oil. A mastic of red lead easily produced overheating, but not so quickly with colza oil as with linseed oil. Valveline, when laid on cold, only caused a dangerous glow when the heat was very intense—equivalent to a 70 pounds evaporation."*

With these results the writer considers that sufficient evidence has been given to prove that circulation is valuable, also that plates as well as tubes exposed to fire should be clear of scale and grease.

There is an indisputable unanimity in the results obtained by all these experiments and those of others whose work cannot be referred to specifically, and they all unite in showing:

(1) That circulation increases heat absorption.

(2) That steam mixing with water spoils the rate of heat absorption in proportion to the amount of steam present, in accordance with Mr. Halliday's experiments.

(3) That the detrimental effect of scale upon heat absorption, and the destructive effect liable if oil accumulates and adheres to the surfaces, are demonstrated by Mr. Hirsch's experiments. The first points to a better output of steam per unit of fuel; the second that circulation to be most useful and fully effective should be of solid water, not mixed steam and water; and the third that the removal of solids also helps to increase the steam output, whilst the removal of oil is shown to be an absolute necessity.

Having proved the point as to the value of circulation, it will be interesting to see how the matter has been dealt with in practice. There is no doubt that the recognition of the value of circulation is to some extent responsible for the extraordinary designs of many tubular boilers. Numerous attempts have also been made to obtain this desirable effect by cross-tubes in furnaces, by bent tubes, rings, etc., in the furnace gases, but they all fail because when steam is formed the solid column of water in them is broken, and circulation is stopped. Various types of baffles have been tried, but they fail because no baffling will turn steam or steam-hot water downwards when it has a free choice to go upwards.

* *Bulletin de la Société d'Encouragement pour l'Industrie Nationale*, 1890, vol. v., page 302; also abstract in *Minutes of Proceedings of the Institution of Civil Engineers*, 1892, vol. cviii., page 464.

Some engineers claim to set up a circulation by the connection at the internal end of the feed-pipe of a nozzle or series of trays, but the impossibility of these assisting to any extent is apparent when the discharge is only equivalent to the rate of steam production, the majority of the incoming water generally becoming steam immediately on discharge, whilst the outflow of the rest is mere subsidence. There is no fireman's hose effect as some imagine.

One inventor (Mr. H. W. Harman), in 1859, patented a propeller fitted at the bottom of the back-end of a boiler and actuated by a shaft passing through the top of the boiler-shell. *

The good features of a perfect circulator are:—(1) That it shall not require outside power to drive it, like Mr. Harman's propeller, but be fully automatic; (2) that it shall start practically as soon as the fires are lit; (3) that it shall always circulate solid water, whatever the heat and pressure of the boiler may be; and (4) that it shall work when fires are banked and the boiler standing until quite cold.

All these good features are present in the "Hotchkiss" automatic circulator,† while to its circulating powers are added the following advantages:—

(5) Deposit, oil, and grease are collected and removed continuously from the boiler while at work; (6) priming is prevented; and (7) by the better expansion of the boiler, repairs are obviated and the life of the boiler is considerably lengthened.

[redacted]

Its power of collecting mud, oil, etc., is apparent each time that it is blown out, tons of mud having been collected from a single boiler after six and eights weeks' working.

At the conclusion of the paper, Mr. Ross conducted a very interesting series of experiments, by means of transparent models of boilers, to demonstrate the theories put forward in the paper.

Mr. A. L. Steavenson (Durham) congratulated the writer of the paper, but he considered that the Hotchkiss apparatus was rather complicated and that the parts were liable to go wrong and give trouble in working. The writer did not seem to recognize the fact that the days of boilers were over, and that, owing to the utilization of rivers and water-falls, coal would soon become a drug in the market.

Mr. C. C. Leach (Seghill) said that he had not found that the old Lancashire boiler, without a good circulation, would be rapidly destroyed. He had had four of them in use for from twelve to fifteen years, without any patent apparatus on them at all. The water used was not particularly good, and the only repairs had been one rivet amongst the four boilers. If properly built, the Lancashire boiler gave the least trouble of any kind of boiler about a pit. The old egg-ended boiler was always out of repair. One thing against the Lancashire boiler was the dead water at the bottom, but that gave no trouble at all, and the economy was nearly equal to any tube boiler.

Mr. J. A. G. Ross (Newcastle-upon-Tyne) said that he was rather surprised to hear the writer speak of the inefficiency of tubes. Those close behind the firebars were liable to be burned out, but he had known boilers to give good results by having tubes put in. At the same time, the method illustrated by the model was excellent; it afforded a means not only of circulating the water but of collecting the mud at the top without opening the boiler, which was a very good thing indeed. With regard to the writer's remarks about the expansion of the boiler, he thought that he was hardly correct. The difference of 2,500° in temperature between one end of the boiler and the other was no doubt in the flame and not in the iron, and the

inference was that the boiler would expand 7 inches, but this was not so; he did not suppose that a boiler 30 feet long would under such circumstances expand an inch. If they had a temperature of 2,500°, it would melt the iron. He thought the apparatus very good provided that it was taken care of.

Mr. W. C. Blackett (Sacriston) asked the author whether he was able to give them any information as to what would be the comparative effect in the coursing of heat through the flues of the boilers. Taking the case of a boiler on coke-ovens, where they could either take all the heat from the flues at once, or, if they chose to do so, take it and course it in the ordinary way: which would be the most likely to give the best results, leaving out the question of the retarding effects due to friction?

Mr. Arthur Ross said that, with regard to the value of circulation in preventing unequal expansion, he could quote one instance which was very apposite. At the Royal Victoria Docks, London, there were five Lancashire boilers, which were condemned on account of the unequal expansion from which they suffered. The boiler-makers were always in the boiler-house, as before one was repaired another was ready to come down. These boilers were working 6 hours and stopped 6 in every 12 hours, pumping 3 up and 3 down tide, the docks not being level with the river. The boilers suffered terribly from unequal expansion, and some six or seven years ago it was decided

[redacted]

water kept solid, but immediately steam was made the water became froth, and there was no further circulation. Supposing that the Hotchkiss was made to circulate from the bottom upwards, no economical result was obtained. With regard to temperatures, he had, of course, quoted an exaggerated case, and was presuming that the heat was absorbed in the metal and that the two extremes of temperature were present. It was to prevent the heat from being absorbed in the metal that circulation was of great assistance, but the example used was only an illustration of extremes. In practice it did not take place to such an extent; the probability was that the expansion of a 30-foot boiler was less than 1 inch; but, if they tried to push the end-plates out even ½ inch, they would have to be very elastic. With regard to the absorption of heat in gas-fired boilers, whether it was best sent through flues or made to travel round the sides, he would not like to form an opinion without further experiments himself. His own experiments were still incomplete, but he hoped to finish them during the forthcoming winter. The question which really arose in the building of boilers was not the total heating surface but the effective heating surface. There was such a thing, however, as having the gases too cool, and in going through the last flue they might be actually extracting heat from the boiler. They must have a big difference between the temperature of the gases and that of the water to secure effective transference of heat.

Mr. W. C. Blackett presumed, therefore, that Mr. Ross condemned the plan of having the side-flues of such a height that they got above the water-line in the Lancashire boiler.

Mr. Ross said that the gases would always keep at the highest point of the flue. This might tend to a superheating action upon the steam; but, in the presence of so large a bulk of water, the tendency would most likely be to evaporate more water. As already pointed out, however, steam being a worse conductor of heat than water would act to some extent as an insulator between the plate and the water, so that there was every probability of the upper plates, exposed to high-temperature gases, being much hotter than the lower ones, thus causing unequal expansion. Where flame or high-temperature gases touched the plates, water should always be on the other side. This action was well illustrated by a steam-filled tube on a water-tube boiler

which was being pressed: the rapid generation of steam blew the water out at both ends simultaneously, circulation was stopped, and often a frequent repetition caused failure of the tube by softening or withdrawal of the end from the drum. Too much heat became stored in the metal.

The PRESIDENT (Mr. John H. Merivale) proposed a hearty vote of thanks to Mr. Ross for his very practical paper, and also for the great trouble that he had taken to illustrate it with such interesting and effective apparatus. He did not agree with Mr. Steavenson that we should be able to do without boilers and that coal would soon become a drug on the market. He held a strong opinion that the result of introducing any new invention or the use of any new substance which at first sight seemed likely to supersede the use of some other, really had the opposite effect, as those who were foolish enough to sell their gas shares twenty years ago, when electric light was coming into use, knew to their cost. Boiler improvements tended to safety and to lessened consumption of fuel, and the smaller the consumption of fuel was, the larger was the demand. This was another theory that he held, and, of course, their interests were bound up in there being a demand for coal.

Mr. C. C. LEACH seconded the vote of thanks.

Mr. Ross briefly acknowledged the vote.

[redacted]

cation from Prof. Lebour on the subject. He had discussed the matter with him, and his (Prof. Lebour's) opinion was that chert was due to the replacement of the limestone by silica. Evidently he (Mr. Atkinson) was wrong in the view that he expressed at the last meeting that possibly their gannister beds might be equivalent.*

Mr. J. P. KIRKUP (Burnhope) said that the samples submitted brought to his mind a visit to Flamborough Head, where, in the chalk cliffs, they found samples of rather better quality than the best of those now exhibited. Apparently the conditions were similar to those found to exist in the Carboniferous Measures.

Mr. W. M. EGGLESTONE (Stanhope) wrote that he agreed with Prof. Lebour that chert was due to the replacement of the limestone by silica. John Mawe referred to the Derbyshire chert, a siliceous substance used by the potters, as being found in the limestone in large detached masses, and in thin strata, near Castleton, Matlock, and other places, and stated that it was "full of marine figures, and animal remains; in which respect it resembles the limestone, as though it had undergone a transition into petrosilex, or what the French call keralite."† It would be interesting to know whether any fossil organisms existed in the Yorkshire cherts.

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* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 233.

† *The Mineralogy of Derbyshire*, by John Mawe, 1802, page 31.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON, JUNE 4TH, 1908.

MR. CHARLES EDWARD RHODES, PRESIDENT, IN THE CHAIR.

PRIZES.

The SECRETARY *pro tem.* reported that the Council had awarded prizes of books to the writers of the following papers, which had been printed in volumes xxxii. and xxxiii. of the *Transactions*:—

"The Courrières Explosion." By Messrs. W. N. Atkinson and A. M. Henshaw.

"Cast-iron Tubbing: What is its Rational Formula?" By Mr. H. W. G. Halbaum.

"An Account of Sinking and Tubbing at Methley Junction Colliery, with a description of a Cast-iron Dam to resist an Outburst of Water." By Mr. Isaac Hodges.

"The Hidden Coal-fields of the Midlands." By Prof. C. Lapworth.

[redacted]

PRESIDENTIAL ADDRESS.

BY CHARLES EDWARD RHODES.

In the first place, it is my duty to thank the members of The Institution of Mining Engineers for the great honour that they have done me in electing me their President for the current year.

My duties have been extremely pleasant, and by no means onerous in character; and, although my term of office has not been marked by any event calling for special notice in the mining world, yet, so far as the Institution itself is concerned, a movement has been inaugurated which may involve a change in the secretaryship and headquarters.

These questions have come to the front, owing, primarily, to the lamented death of the late Mr. M. Walton Brown, who had so ably fulfilled the secretarial duties appertaining to The Institution of Mining Engineers almost from its formation, having been appointed in 1891.

A considerable section of the members of the Institution have for some time been of the opinion that some steps should be taken which might, if possible, have the effect of giving The Institution of Mining Engineers a position, not only in this country, but in the world, a position which appeared to them that up to now it had not held. It has been felt that as the mining industry is the most important industry in the country, inasmuch as on it depends that vast commercial prosperity which has made the United Kingdom what it is, those who are responsible for its conduct, and on whose skill and ability its future entirely depends, should be members of a body the possession of whose diploma would be recognized the world over as being, so to speak, an "Order of Merit" which would carry with it similar recognition to that of the membership of the Institution of Civil Engineers.

As President of the Institution, I have, as far as possible, endeavoured to keep an absolutely impartial attitude in connection with this suggestion, but I think it desirable to draw attention to it, so that the whole of the members may have before them the

facts connected with the movement, which has been initiated solely with the object of, if possible, improving the status of the mining engineer.

I have had an opportunity of hearing opinions both for and against the proposal.

All must recognize, and I am certain do recognize, the fact that The North of England Institute of Mining and Mechanical Engineers is, so to speak, the parent of all the other Institutes that have sprung up throughout the country; and that, owing to the liberality of the members of that Institute, The Institution of Mining Engineers, or the federation comprising within it all the various individual institutes, was started in life on lines not only very economical in their character, but with every advantage which would be likely to conduce to success, owing to their *Transactions* being edited and published under the auspices of one of the experience of the late Mr. M. Walton Brown.

It has, however, been felt that although the success attending, if I may term it, the federation of the various institutes, has been of the greatest benefit to the profession, the mere membership of that Institution does not carry with it the prestige that it should do.

On these grounds, therefore, and I think solely on these grounds, it has been thought that if headquarters could be established in London, and The Institution of Mining Engineers put more on the lines of the Institution of Civil Engineers, the re- [redacted]

of opinion: but I venture to suggest that it is well worthy of the consideration of all connected with the coal trade; and it is also one that requires the most careful thought, before any step is taken which must have a permanent effect whether for good or ill on the future of this Institution.

It is most difficult in a Presidential Address to introduce any new topic, and when I read the able addresses which have been delivered by my predecessors in the office that I now hold, I feel that it is impossible for me to strike new ground; and it is with extreme diffidence that I venture to deal with some of the well-worn topics which have from time to time been placed before you.

Your late President gave a résumé of the mining industry and the legislation connected with it, which covered the ground for many years past; but he laid stress, notwithstanding what had been done in the past, on the necessity for higher education, in order to enable the mining engineer to deal with the very much greater problems that will have to be dealt with in the future.

You are all aware that twenty-five or thirty years ago a shaft of 900 to 1,200 feet in depth was considered a deep one; but the enormous rapidity with which the coal-fields lying nearest to the outcrop have been exhausted—especially so far as the most important seams are concerned—has brought about the necessity of developing seams at much greater depths and under very much more difficult conditions than prevailed in the past; and collieries are, in consequence, being opened out at depths far beyond what was thought within the scope of practical possibility thirty or forty years ago.

In some districts, the sinking of these shafts, owing to the character of the strata through which they are sunk, carries with it difficulties which require a great amount of engineering skill to surmount and involve vast outlay. Collieries have been sunk where quicksands have had to be dealt with, and where the pumping of the water has been accompanied by difficulties, apart altogether from the mere pumping of the water, owing to the fact that the draining-off of the water from the sand has caused a movement of the surface, which has had the effect of interfering with the stability of the surface for the erection of the machinery and other works. This is a difficulty that has been successfully surmounted in one case that I am aware of, and probably in others also.

In other cases, where the water-bearing strata are of great thickness, the problem presents itself as to what depth it is feasible to put in tubbing, and whether it is desirable to tub up to the surface, or to tub up part of the way, pumping the rest. There is then, again, the question of finding a second or third feeder of water at a great depth from the surface, and, if it is of any magnitude, the best way of dealing with it, after the upper feeders have been successfully dealt with. There is no doubt that where the water-bearing strata are, say, 1,200 feet or more thick, the best way of dealing with them is a problem which will put to very practical proof the ability and skill of the mining engineer who has to cope with the difficulty.

The depth to which tubbing can be put in is a matter of the greatest importance; whether the present type of tubbing is the best that can be designed for resisting the enormous pressure which it would have to sustain, say, at 900 feet in depth; whether the material used generally now is the most suitable for the purpose, or whether steel should displace iron; and whether it would be advantageous to fill up the back of the tubbing solid with improved concrete or not, are most important problems.

In connection with the question of tubbing, the size of the shaft is a serious matter. One question, however, appears to dovetail in with another in such a way that nothing can definitely be decided as to details until the scheme as a whole is mapped out.

To illustrate my point:—To develop a coal-field at a depth of,

[redacted]

the difficulty can be got over, with the improved appliances for loading and unloading the cages now in vogue; and it seems to me, therefore, that one of the most important matters in connection with the development of these deep mines is that of ventilation, and what quantity of air can be obtained with high water-gauges down shafts of moderate size.

I am of opinion that at great depths the cooling down of the strata and working-places, so as to enable the workmen to work in comfort, will necessitate improved methods of splitting the air. Dividing it into separate districts will be a matter of great importance, and it is probable that auxiliary fans to assist the main ventilating machine may be advantageously used, not so much probably on account of the question of diluting any gas that may be given off, but to improve as far as possible the conditions under which men and horses may have to work.

A further decision that must be come to by the mining engineer responsible for opening out a colliery under the conditions described will be the method of working. Some engineers boldly advocate taking out the whole of the coal from the shaft-bottom, and this has been done with satisfactory results; but what the effect would be of adopting this course with a long length of tubbing in the shaft is a very moot point, and it is doubtful whether under such circumstances the advantages to be derived would be at all commensurate with the risk.

In my judgment, however, there is no intermediate course between taking the coal out from the shaft-bottom and leaving a very large shaft pillar and then taking all the coal out beyond it.

Considerable difficulty has been experienced in some instances with the "grinding" set up against the shaft pillar by the weight incidental to the removal of the coal being thrown in the first instance on to the edge of the pillar, this grinding process going on for some two or three years, and followed in one case by a gob-fire, which was attributed to the disintegration I have indicated.

To obviate this, in one case I have adopted a plan of going a considerable distance beyond the shaft pillar, and have then opened out both in the direction of the pillar and away from it. This method has enabled the weight to be settled away from the pillar; and although the process of development was in the first instance retarded, the results have been satisfactory. What-

ever method, however, may be adopted, the responsibility of the mining engineer is an onerous one.

These deep mines will also, in all probability, be very dusty, and the arrangements which are made in the first instance for dealing with this question will have a very important bearing on the efficiency in the future of any plans that may be devised for what is one of the most dangerous elements that has to be contended with in mining.

I lay stress on this point, because the difficulty of dealing efficiently with dust in old collieries is very great, and however anxious owners or managers may be to cope with an acknowledged evil, it is almost impossible for them, in some instances, to do so efficiently. Watering as a general rule is impracticable, and mere damping the air, while it does very considerable harm to the roadways in many cases, is of little practical use. The question, therefore, of so laying out and working the pit from its inception as to reduce the dust to a minimum is all important.

The question of the type of winding-engines, guides in shaft, load and consequent strength and size of ropes, are all important matters, many of which have from time to time formed the subject of discussion; but day by day new developments are taking place, and most of these mechanical problems are rapidly being solved satisfactorily.

One of the most important is the type of winding-engine, not so much as to whether it is compound or not, but the type which

[redacted]

I am afraid that I am wearying you by this cursory sketch of some of the problems with which the rising generation of mining engineers will have to deal; and my apology must be that I am anxious to impress on them the fact that, if they are to cope with the difficulties that I have endeavoured to indicate, they can only do so by taking advantage of every opportunity of acquiring practical knowledge of a wide and varied character, and also of availing themselves of technical training in the numerous scientific subjects which it is essential that they should possess, and for obtaining which there are now such excellent facilities.

When, however, we remember what has been done by our sister profession, the civil engineers, to the Institution of which many of us have the honour to belong; and when we see the enormous difficulties which have been surmounted by their skill, and the stupendous works which they have planned and carried out to a successful issue, I feel sure that mining engineers will rise to the occasion, and that during the next thirty years undertakings will be carried out, which, while not so apparent to the public eye, nevertheless involve difficulties equal in character to those which have been surmounted so successfully by the sister profession.

The various institutes of the country comprised in The Institution of Mining Engineers have been in the past, and will be in the future, the means of doing an enormous amount of good by enabling the interchange of ideas between one mining engineer and another to take place through the papers which are read from time to time and the discussions which take place upon them. Papers are read by the ablest of our engineers, and are published in the *Transactions* of this Institution, and therefore place within the reach of all a means of acquiring information, of which if we do not take full advantage the fault lies with us, while the knowledge available cannot fail to be of enormous service to those who follow after us.

In conclusion, therefore, I would urge that no change be embarked upon in connection with the management of this Institution which is not likely to conduce to its best interests. I have, consequently, endeavoured, however imperfectly, to indicate the advantages that we have derived from being members of it in the past, in the hope that the members will rally together in a united endeavour to place it on the strongest possible foundation in the future.

Mr. H. C. PEAKE (Walsall), in moving a hearty vote of thanks to the President for his able Address, said that instead of wearying the members, as the President had suggested, it was one of the shortest sermons that he had listened to for a good while; otherwise it was everything that a Presidential Address should be.

Dr. R. T. MOORE (Glasgow), in seconding the motion, endorsed all that Mr. Peake had said, and said that the Address was a most interesting one, and of great value to the Institution.

The vote was cordially adopted, and was briefly acknowledged by the PRESIDENT, who thanked the members for the resolution.

Mr. JOHN CADMAN read the following paper on the "Mineral Resources of Trinidad":—

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MINERAL RESOURCES OF TRINIDAD.

By JOHN CADMAN, M.Sc., F.G.S., H.M. Inspector of Mines.

Introductory.—Situated off the north-eastern corner of South America, in close proximity to a country possessing abundance of mineral wealth, it is not surprising that Trinidad possesses mineral resources of considerable importance. Whilst some of the minerals have been proved to exist in enormous quantities, others are still undergoing the searching investigation of prospectors.

The island of Trinidad has an area of some 1,750 square miles, and a population of upwards of one-quarter of a million. The surface of the island, with the exception of the portion under cultivation, is covered with excessively dense and luxuriant vegetation—so much so that much of the high woods is only penetrated with great difficulty.

In presenting this record of the mineral resources, the writer proposes to describe very briefly the minerals known to exist, and to dwell more fully upon the resources of commercial importance.

Geology.—The geology of the island is comparatively simple, but the enormously dense vegetation covering the surface renders the collection of geological evidence a most difficult and arduous task.

The northern portion of the island, stretching from the Bocas, the narrow and truly gorgeous straits which separate Trinidad from Venezuela, to the promontory of Galera Point, is occupied by hills rising in places to upwards of 3,000 feet.

This northern range is composed of a series of metamorphic rocks of doubtful age, consisting of limestone, graphitic schists, mica-schists, talc-mica-schists, quartzose grits and schists, folded and refolded to an enormous degree.

To the south of this range the surface features present a series of gentle undulations, with here and there more prominent landmarks resembling roof-ridges to be seen in San Fernando

Hill and Dunmore Hill. Only a small part of this area are composed of Cretaceous rocks, which strata varies from soft sandstone, containing shining flakes of mica, to sandy clays and fine clays, whilst at the higher horizons thin beds of limestone are to be found.

The remainder and greater portion of the island is made up of Tertiary rocks, which have been laid down upon an eroded surface of the older rocks. These rocks are a series of sands, clays, lignite beds, and oil-bearing sandstone, with a total thickness of upwards of 6,000 feet.

From the upper horizon, fossils Pliocene in facies have been obtained; from the middle, Miocene; and from the lower, Eocene in type.

The structure of the Tertiary group is of infinite importance to the mining engineer, in that the series of folds bring within workable depths the horizons which are likely to contain productive minerals. Four principal anticlines have been recognized, extending in a general east-and-west direction across the southern part of the island. Several subsidiary anticlines have also been located, which appear only over limited areas.

The first or northernmost anticline passes from a point on the east coast to the town of San Fernando. The second anticline extends from a point north of Mayaro Bay, to the Vance river on the west coast, and upon this anticline the famous Pitch Lake is situated. The third anticline extends from Mayaro Bay on the [redacted]

part of the range. Segregation veins and stringers of quartz occur in a country rock composed of a series of mica, talc-mica, and quartzose schists.

Iron Ores.—Hæmatite and magnetite have been found in the Santa Cruz valley, the latter to a considerable extent, so far as surface exposure goes, but little, if any, attention has been given to it.

Graphitic Schists.—Decomposed graphitic schists occur in the northern range. No true vein of graphite has been located, but the graphitic schists on the Arima Blanchisseuse road are at this moment being worked. An analysis of a sample of this product yielded the following results:—

	Per cent.
Water	11·68
Ash	67·80
Organic matter	20·52
Total	100·00

The organic matter contained 16 per cent. of carbon (graphite).

Limestone is worked in many parts of the northern range by quarrying. It is chiefly used for road-metal, but some quarries contain over 98 per cent. of carbonate, in which case the stone is calcined, and finds a ready market. The question of utilizing the local muds and limestone for the manufacture of cement was carefully considered by Prof. Carmody and Mr. E. H. Cunningham-Craig in a report to the Trinidad Government.* Cement has been made on a small scale with the material, and the tests proved highly satisfactory. With the large demand for cement which obtains in Trinidad and the adjacent islands, it is very likely that within the near future a success will be made in its manufacture.

Economic minerals known in the Cretaceous rocks need not receive any attention, other than to note that much of the road-metal from which the colony obtains its excellent roads is got from quarries in the Cretaceous formation.

To the Tertiary rocks the writer wishes to draw special attention. Coal, manjak, asphalt, and petroleum are the economic products, all of which appear to have a common origin. In

* *Portland Cement as a Local Industry*, Trinidad Government Report, 1905 [C. P. No. 4].

many parts of the island beds of lignite are found associated with carbonaceous shales and beds full of plant-remains, whilst in other parts at the same horizon fossilized vegetable matter is entirely absent, and beds saturated with petroleum appear.

The carbonaceous portion of this area predominates in the north, whilst the petroleum phase is found more in the south of the island.

Coal.—Wall and Sawkins* point out the localities in which beds of lignite were exposed at the surface; they further detail some tests made by H.M.S. "Buzzard" in 1859, from coal quarried on the east coast.

After consideration, the Cunupo area, in the neighbourhood of Sangre Grande, was selected for a special test of these Tertiary lignites; a careful geological survey was made, and several borings were put down. The rocks in this locality are composed of a series of soft shale and sandstone lying unconformably upon hard Cretaceous beds. Two seams of lignite were discovered dipping at an angle of 40 degrees, having a maximum thickness of 4 and 5 feet respectively. Each of these seams was opened up by driving a cross-measure drift to intersect them; levels were driven on the strike for some distance, and a fair quantity of coal was taken out for practical tests, which were conducted on the Government railway. These tests were quite satisfactory, and the analysis of samples of each seam were as follows:—

Seam A. Seam B.

[redacted]

Lignite also occurs in several localities in the north-east of the island, but little attention has been paid to it.

Bituminous Minerals.—So far as the economic bituminous minerals are concerned, particularly asphalt, Trinidad holds its own with any country in the world. In dealing with this section of the paper, the writer proposes first to describe such minerals as asphalt and manjak, which are being commercially worked on a considerable scale to-day, and then to deal with the subject of petroleum, which in the near future is likely to place Trinidad in greater prominence than she has hitherto enjoyed.

Each of these minerals are so intimately connected with one another that it is difficult to separate them in discussing their mode of origin. The sandstone containing petroleum appears to be the original source of supply of both the manjak and the asphalt. There are three main horizons of oil-bearing strata, namely: the first (Galeota) near the base of the Tertiary; the second (Rio Blanco), 4,000 feet above the first; and the third (La Brea), 1,500 feet above the second. Each of these horizons consists of coarse, porous sandstone, containing petroleum.

Manjak.—A series of fine, stiff Tertiary clays, usually of a bluish colour, weathering to a yellowish-brown, some 800 feet or so in thickness, occurs in the north of San Fernando in the neighbourhood of Marbella. The dip of these clays is roughly from 20 to 50 degrees north-north-west. Through these clays veins run in various directions, in which intrusions of liquid or semi-liquid bitumen have occurred. Solidification has taken place, and a mineral called "manjak" has been formed.

One vein has been traced at the Vista Bella Mine, for a distance of some 400 feet horizontally and over 250 feet in vertical depth. This vein runs in an average direction north-north-east, and hades from 55 to 70 degrees. It approaches in parts more or less a lenticular mass, varying in thickness from 11 to 33 feet at the 200-foot level. Other veins are known, varying in thickness from 6 inches upwards, but the whole of the area has by no means been proved.

The physical structure of the manjak presents three distinct types:—

(1) An amorphous variety, resembling coal, from which the early discovery of the deposit led to the belief that a seam of coal was being worked; indeed the mineral was sold as coal, until it was found that it melted and ran through the firebars of the furnace upon which it was used.

(2) A columnar variety, to some extent resembling the amorphous variety, but occurring with perfect columnar jointing, running at right-angles to the margin of the vein. Perfect hexagonal prisms are obtained, and the local name of "pencil-manjak" has been given to this variety.

(3) The third variety, known as "lustrous or merivale manjak," resembles the Barbados manjak. It has a very bright lustre and conchoidal fracture.

This deposit appears to owe its origin to the petroleum-bearing rocks lying below, from which the manjak, in a semi-fluid state, has intruded under pressure into the soft clays above, following the lines of weakness presented by the fissures.

A carefully selected series of analyses, of samples taken from different depths has been made by Prof. Carmody, and the following results have been recorded:—*

"The bitumen in its ascent appears to have (*a*) lost water slightly; (*b*) suffered in diminution in the percentage of petrolene; (*c*) gained in mineral matter at the expense of organic matter. An analysis of a typical sample was: Water, 1·00 [redacted]

ing lifts to the rise; the goaf is then packed tight with *débris* from the surface, sent down by means of a square wooden tube, called a "chute," with sliding doors at intervals. The labour employed in the mines is entirely native (negro). Fig. 1 is a photograph of one of the mines.

There is usually a good natural ventilation in the mine; but fans have now been erected, on account of the greater difficulty in ventilating the lower levels. An explosion occurred in the Vistabella Mine in December, 1904, causing the death of 17 miners. At this time the mines were being worked with naked lights.

FIG. 1.—VISTABELLA MINE.

The writer has paid special attention to the gases found in manjak mines, and possibly it will not be out of place to state here some of the results of this research. A sample of gas was taken from the roof of a heading which extinguished a safety-lamp when raised into it. The meanest indication of a fire-damp cap was detected—so slight, in fact, as to raise some doubt as to the presence of fire-damp at all. The sample was analysed, and gave the following results:—

	Per cent.
Oxygen...	14·00
Carburetted hydrogen	11·10
Hydrogen	1·60
Nitrogen (by difference)	73·30
Total	100·00

The analysis proved the gas to be of a highly dangerous character, and only requiring the addition of more oxygen to render it an explosive mixture.

Other instances of a similar nature were discovered. On discussing the matter with Dr. J. S. Haldane, he suggested that the deficiency of oxygen was due to the absorptive properties of the manjak. It seemed quite clear that whatever was the cause, oxygen was being absorbed much more rapidly than under similar conditions in coal-mines.

Prof. P. Carmody was good enough to undertake some experiments to demonstrate this point. The manjak used was of the lustrous variety, showing no trace of the columnar structure, and of the following composition:—

	Per cent.
Water and volatile matter	4·56
Organic matter	90·96
Mineral matter	4·48
Total	100·00

The organic matter contained:—

	Per cent.
Bitumen	90·60
Other than bitumen	0·36
And contained petrolene	15·60

About 30 grammes of this sample, freshly taken from the mine, were broken to the size of small peas, and confined with [redacted]

A similar sample, which had been exposed to the air of the laboratory for a week, was enclosed for 5 weeks, and the analysis of the air drawn off showed the following change:—

	Per cent.
Oxygen absorbed	6·10
Required for carbon dioxide and carbon monoxide ...	0·85
Oxygen absorbed, and not used in forming gaseous oxidation products	5·02
Diminution in petrolene	1·04

These experiments clearly show that manjak has the property of absorbing oxygen from the air, and confirms the conclusion drawn from the analyses before mentioned.

Further samples of air from working-places in the manjak mine gave the results contained in the following table:—

TABLE I.—ANALYSES OF SAMPLES OF AIR FROM WORKING-PLACES IN MANJAK MINES.

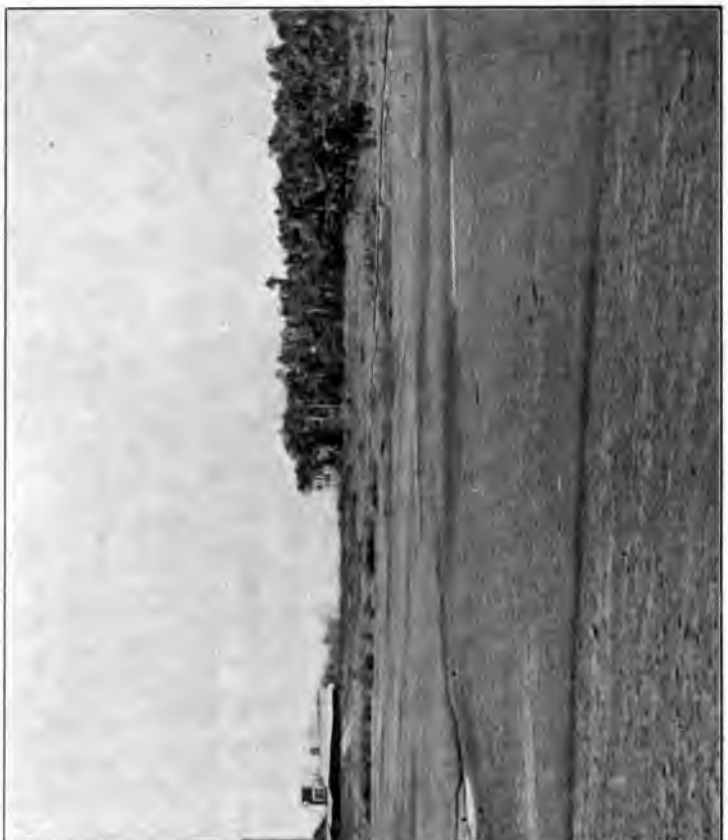
Description.	Marbella Mine.				Vistabella Mine.
	No. 118 Level, North End.	No. 118 Level, Hole in Roof.	No. 118 Level, South End.	No. 90 Level, End.	No. 200 Feet Level, End.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Carbon dioxide ...	0·60	0·50	0·80	0·20	1·40
Carbon monoxide ...	trace	trace	*nil*	trace	*nil*
Unsaturated hydro-carbons	0·75	*nil*	*nil*	0·20	0·20
Carburetted hydrogen	0·40	0·80	0·40	0·60	0·75
Oxygen	19·40	19·60	19·30	19·50	19·00
Nitrogen	78·85	79·10	79·50	79·50	78·65
Totals	100·00	100·00	100·00	100·00	100·00

Asphalt.—The asphalt deposits of Trinidad, to which reference has often been made, and which have been described as one of the wonders of the world, are situated at La Brea on the south-western corner of the island.

Many theories have been advanced to account for their origin, and the one now generally accepted is that suggested by my former colleague, Mr. E. H. Cunningham-Craig, in his memoir on *The Oil-fields of Trinidad.**

The asphalt deposit is divided into two areas, the Pitch Lake, and the La Brea village deposit: the latter being an overflow from the lake, which at one time filled a narrow ravine running in a northerly direction from the lake, towards La Brea Point, and extending over an area of some 70 acres.

* Trinidad Government Report, 1907 [C. P. No. 60].



[redacted]PH TAKEN FROM THE CENTRE OF THE LAKE, LOOKING TOWARDS THE DRYING STATION.

[redacted]

The Pitch Lake is a curious circular mass of asphalt, covering an area of 137 acres, and resting on the crest of an anticline. To the denudation of an exposed cap of this anticline and the slow breaking down of the oil-bearing sands, together with oxidation and evaporation of the more volatile constituents, the Pitch Lake owes its existence.

The Pitch Lake (fig. 2), which is situated about 1 mile from the sea, and is 130 feet above sea-level, presents the appearance of a patch of dark pavement, with natural furrows running in every direction, forming water-courses, from which the surface-drainage extends to an artificial outlet cut in the rim of the lake. The surrounding margin of the lake is covered with rank grasses and palmetto of a luxuriant type, and small islands, dotted here and there on the lake, maintain similar vegetation. These so-called floating islands have been formed either by accumulation of wind-blown material, or from detached portions of the sides finding their way, by the action of convection currents, into different parts of the area. Such flows can be traced at the present time, and these islands are gradually moving to the seat of active excavation.

The extent of the deposit is only conjectural; borings have been put down in several parts of the lake, those nearest the sides, after passing through some feet of asphalt, passing into the oil-bearing sands below. One hole near the centre reached a depth of 135 feet without touching the bottom.

The appearance of bitumen in the fine brown superficial clays surrounding the deposit is apt to mislead one in drawing conclusions as to the origin of the deposit. Much light has been thrown on this subject by the research of Mr. Clifford Richardson,* who shows very clearly the absorptive properties of fine clays for bitumens.

Fig. 3 shows a flow of asphalt, passing over some of these clays, in which can be seen the columnar structure taken up by the fine clays, due to the absorption of bitumen from the asphalt and subsequent contraction.

An analysis of this clay, having a density of 0·7, gave the following results:—

* "The proximate Composition and physical Structure of Trinidad Asphalt,' by Mr. Clifford Richardson, *Transactions of the American Society for Testing Materials*, 1907.

	Per cent.
Water	2·60
Organic matter ...	56·70, containing 28·10 per cent. of bitumen.
Mineral matter ...	40·70
Total	100·00

Freshly excavated asphalt is saturated with water and to a great extent emulsified.

[redacted]

It is often stated that the Pitch Lake is inexhaustible; but as shown by Prof. Louis,* and confirmed by these figures, the

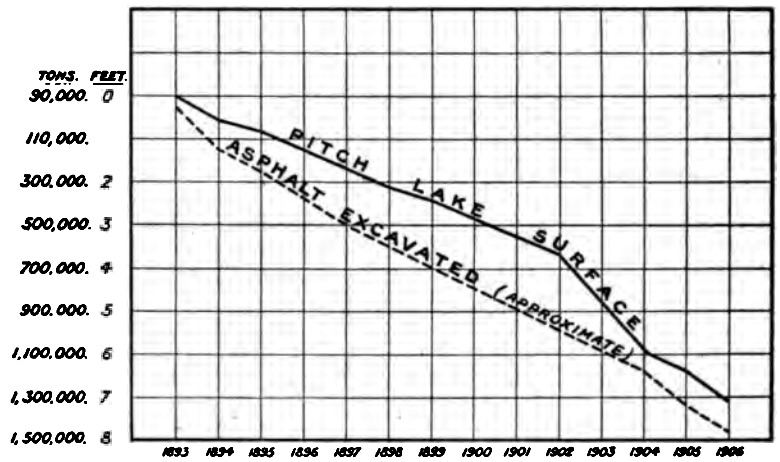


FIG. 4.—DIAGRAM SHOWING APPROXIMATE AMOUNT OF ASPHALT EXCAVATED, AND CORRESPONDING SUBSIDENCE OF PITCH LAKE SURFACE.

rate of extraction corresponds for practical purposes with the rate of subsidence.

FIG. 5.—LOADING ASPHALT ON THE PITCH LAKE.

* *Report of the Asphalt Industry Commission* (with appendices), by Messrs. Henry Louis and J. W. Gordon, 1902.

[redacted] Wharf, showing Aërial Ropeway and Houses.

The extraction of the asphalt from the lake is exceedingly simple. The deposit readily breaks to the blow of a pick. When cut, the deposit has the appearance of black Gruyère cheese. An endless-rope tramway passes on to the lake, describing a path round which it has been found most convenient to excavate; the railway is supported on round props, which become totally embedded in the asphalt in the space of a week. A gang of men are employed regularly rolling these props forward on to fresh ground, in order to prevent the submergence of the track. At the curves the track is guyed by steel ropes to standards permanently fixed in the solid ground at the sides.

After the asphalt is cut, it is loaded by hand into trams holding approximately 10 cwt. each (fig. 5). Digging continues round this track day after day—the natural level of the deposit is assumed in a day or so, so that digging is almost continuous from the same spot. The asphalt is conveyed to a weighing station, where the bodies of the trams are removed to an aërial ropeway, weighed, and conveyed to the loading wharf, which projects into the Gulf of Paria (fig. 6). Upon this pier houses are built to accommodate the European population. This wharf is capable of berthing two vessels of almost any size, and provision is made for simultaneous loading. As much as 1,000 tons per day can be put out in this way.

The greater part of the asphalt is shipped in a crude state, but much of that sent to European markets is dried before shipment. This is brought about by depositing the asphalt into a large hopper containing steam-coils, through which steam is passed at a pressure high enough to raise the temperature of the asphalt sufficiently to drive off all moisture, namely 302° Fahr. (150° Cent.). After drying, the asphalt is poured in a molten state into barrels, in which state it is shipped.

Another and more crude method is also adopted. The asphalt is placed in a series of open stills, under which wood-fires are burning; sufficient time is allowed for the moisture to evaporate, and the molten asphalt (called "épuré") is bailed into barrels for shipment. This method is extremely wasteful and expensive.

The change brought about by this artificial drying is as follows:—

FIG. 7.—ASPHALT EXCAVATION IN LA BREA VILLAGE.

[redacted]

	Per cent.
Water	2
Mineral matter	37
Bitumen	50
Organic matter (non-bituminous)	10
Total	99
Softening point	158° Fahr. (70° Cent.)
Flowing point	203° Fahr. (95° Cent.)

The saving in freight by the removal of 25 per cent. of water is a considerable advantage.

The asphalt deposit of La Brea village presents a totally different appearance from that already described—a more dismal

FIG. 9.—ASPHALT CONE ON A PETROLEUM OUTCROP.

picture than the area in which these operations are conducted could not be imagined. So much digging has taken place that the original surface upon which the village of La Brea formerly stood has subsided as much as 15 to 18 feet. The work of excavating a village-lot first of all entails the removal of earthy matter, then cutting and cleaning any pitch that may from time to time be found in the land. Excavations up to 20 feet deep are made in pursuit of this mineral. The village asphalt is not so fluid as the lake pitch, and, in consequence, the rate of levelling up is considerably longer. Figs. 7 and 8 show a village lot in course of excavation.

Pitch taken from this deposit is loaded by means of lighters off La Brea Point. Native labour, both male and female, is employed in the working.

Petroleum.—With such an asphalt deposit, a natural product of petroleum, it is not to be wondered that attention has been directed to endeavours to discover the parent rocks from which such enormous deposits have been produced.

The main oil-horizons have already been described, and also the general structure of the oil-bearing rock. It is now necessary to describe more fully the chief surface-indications as they are to be seen in Trinidad. "Oil-shows," as they are termed, may be classified as follows:—

(*a*) Outcrops showing actual oil-bearing rocks, namely, sandstones impregnated with oil, the oil slowly exuded and drying into a sticky asphalt.

(*b*) Soft asphalt cones, with an orifice from which the material is slowly oozing (Fig. 9).

(*c*) Oil exuding from the ground and covering the surface of water with a brown film of oil.

(*d*) Gas bubbling up through water and oil. Deposits of asphalt formed by the gradual drying-up of the oil, are characteristic of actual outcrops; and such shows are evident, where the oil-bearing rocks are at or comparatively near the surface.

[redacted]

Exploration was first commenced by a Canadian Syndicate, of which Mr. Randolph Rust was the pioneer. Wells have been drilled in the south-east of the field, many with very encouraging results. Wells are also being put down under the direction of Mr. A. Beeby Thompson to the south-west of the field, at the instance of a strong British directorate. Fig. 11 is a photograph of one of the prospecting wells.

FIG. 10.—MUD VOLCANO IN ERUPTION.

The details of the drilling and the methods employed do not fall within the scope of this paper.

Conclusions.—Some 500 square miles of oil-fields are known to exist, and over a large area a careful geological survey has been made.

The many indications of petroleum have been deemed, by those whose experience renders them competent to judge, exceptionally favourable, and there seems little doubt that Trinidad will, ere long, add considerably to her productive mineral resources by being capable of placing petroleum upon the market in enormous quantities.

[redacted] 11.—PROSPECTING WELL IN HIGH WOODS.

APPENDIX I.—ANALYSES OF GAS AND WATER FROM THE PITCH LAKE.

The following interesting analyses were made by Prof. Carmody, of samples collected by the writer:

Gas from Pitch Lake, bubbling through pools of water on the surface of the lake.

	Sample No. 1. Per cent.	Sample No. 2. Per cent.
Sulphuretted hydrogen	1·78	1·0
Carbon dioxide	12·02	19·0
Unsaturated hydrocarbons	1·40	0·2
Carbon monoxide	0·20	1·1
Marsh gas	not determined.	1·7
Hydrogen	not determined.	3·8
Nitrogen (by difference)	not determined.	73·8
Total		100·6

Sample of water collected from the centre of the Pitch Lake.

Reaction acid to litmus	
Total dissolved gas absorbable by potash, in cubic centimetres per litre	87·100
Dissolved hydrogen sulphide, in grammes per litre	0·007
Sulphur present as alkaline sulphide, in grammes per litre ...	0·038
Total sulphur other than sulphate, in grammes per litre ...	0·144
	Per cent.
Total solids, dried at 230° Fahr. (110° Cent.)	1·288
Hydrated water, etc. ; loss, 236° to 356° Fahr. (110° to 180° Cent.)	0·026
Loss on ignition above 356° Fahr. (180° Cent.)	0·078
Lime	0·011
Alkalies as chlorides	1·104
Sulphates as SO_3	0·022
Phosphates as P_2O_5	0·005
Iron	Small trace

APPENDIX II.—ANALYSES OF TRINIDAD PETROLEUM.

Oil from a well, 16 feet deep, on the Rio Blance. The oil-sand gave the following analysis :—*

Specific gravity	0·96
Mineral matter, per cent.	0·04

Results of fractional distillation : –

Boiling point, about 158° Fahr. (70° Cent.)	Per cent.
Petroleum spirit, below 302° Fahr. (below 150° Cent.)...	8·00
Illuminating oil, 302° to 572° Fahr. (150° to 300° Cent.)	45·00
Lubricating oil (above 300° Cent.)	10·10
Loss	7·90

Sample taken at the surface of a bore-hole, 60 feet deep, to the west of the Pitch Lake :—*

Specific gravity	0·95
Mineral matter, per cent.	0·02

* *Trinidad Oilfield*, by Mr. E. H. Cunningham-Craig, Trinidad Government Report, 1907 [C.P. No. 60].

On distillation, the following results were obtained :—

	Per cent.
Water	1·2
Petroleum spirit	12·8
Illuminating oil, 302° to 572° Fahr. (150° to 300° Cent.)	36·0
Lubricating oil, above 572° Fahr. (above 300° Cent.) ...	12·3
Residual bitumen	5·7

Samples of oil from Mayaro-Guayaguayare district; analyses by Prof. Wyndham R. Dunstan, M.A., F.R.S.*

	No. 1 Well, 1904. Per cent.	No. 2 Well, 1904. Per cent.	No. 3 Well, 1904. Per cent.	No. 4 Well, 1904. Per cent.	Lizard Spring Well, 1904. Per cent.
Light petroleum	23·0	12·0	7·6	1·0	1·0
Kerosene	39·5	30·0	43·1	21·0	54·0
Heavy oils distilled above 572° Fahr. (300° Cent.) under reduced pressure. Fraction I.	26·0	26·6	12·6	48·2	24·2
Heavy oil distilled under reduced pressure. Fraction II.	7·0	20·0	32·0	25·0	11·2
Coke and loss	4·5	11·4	3·7	4·6	9·6
	100·0	100·0	99·0*	99·8	100·0
Specific gravity of crude oil	0·894	0·913	0·856	0·933	0·900
Flash-point of crude oil ...	35·6° Fahr. (2·0° Cent.)	48·2° Fahr. (9·0° Cent.)	67·1° Fahr. (19·5° Cent.)	176·0° Fahr. (80° Cent). (Approx.)	140·0° Fahr. (60° Cent.)

* Water, 1 per cent.

Nos. 1 and 2 wells: Situated on No. 4 or southern anticline, representing oil from Galeota sandstone.

No. 3 well: Two miles south of the southern anticline, in somewhat higher beds.

No. 4 well: Situated in centre of syncline between Nos. 3 and 4 anticlines, tapping the highest oil-bearing stratum.

[redacted]

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The President (Mr. C. E. Rhodes) said that he had much pleasure in proposing a vote of thanks to Mr. Cadman for his very interesting paper, which covered a great deal of ground. He was sure that the members had listened to the paper with the greatest possible attention, as Mr. Cadman had given them a great amount of information which was entirely new.

Mr. BENNETT H. BROUGH (London) said that he wished to endorse the President's testimony to the value of the paper. A good many years ago he had had an opportunity of spending some time in the West Indies, and he had the greatest difficulty to obtain any information with regard to the mineral resources of those islands. A paper like the present one would have been invaluable to him, and it was such papers that made their *Transactions* of such inestimable value for reference purposes.

Unfortunately, he had not spent any time in Trinidad, and so was unable to add anything to the interesting facts which the author had brought before them. The island in which he had spent most of his time was St. Lucia, where there was very little of mineral interest. There were some deposits of sulphur which were worked in a small way for the manufacture of sanitary pipes, and they were of interest geologically because one saw the deposits in actual process of formation as a result of volcanic activity.

Altogether, he thought that in a good many of those islands there was a great deal to be done in the way of further study of their neglected mineral resources. The great difficulty in working them seemed to be the question of labour. The negro labourer was a most difficult person to work with if one had any surveying operations to do, as he had not the slightest idea what a straight line was. He had found that the negro's lack of power to grasp facts went still further, because he had actually had some men working for him who were not able to appreciate the value of

[redacted]

circumstances, to make a very valuable fuel. In many parts of the world lignites were largely used which contained over 20 per cent. of water, and very much more than 8 per cent. of ash. As he was speaking entirely from memory, he could not give the exact figures.

The author had referred to the erratic way in which the seam varied in thickness, but he thought that was usual; lignite-seams generally did vary rapidly and capriciously in thickness. The author had also referred to lignite "containing coke, 42·85 per cent." He was very sorry to confess that he did not understand that, but he always thought that lignites were lignites principally because they did not yield coke.

Mr. A. Beeby Thompson (London) said that he took part with exceeding pleasure in the discussion, because he had spent a considerable time in Trinidad, on the particular work to which the author referred in his paper. There were very many interesting points raised, but he did not think that the author had sufficiently brought out the details. For instance, he observed that he was very modest in his reference to the manjak-mines. He believed that the author had called attention, on arrival in Trinidad, to the danger of working those mines without proper lamps. Had his advice been taken, there would not have been the explosion in the mine which took place shortly afterwards and killed seventeen men.

With reference to the Pitch Lake, he did not think that it was generally understood how enormous and valuable a deposit that had been. It was certainly one of the most important deposits of asphalt in the world, and he did not think that anything to be compared with it had been discovered so far. The author did not mention that since the Pitch Lake had been worked the Government had imposed an export duty of about 5s. a ton on the pitch, which had brought an income to the Government of about £400,000 since the lake had been worked. In a struggling new colony, an income of £400,000 was a most valuable sum to receive, and had done a good deal towards opening up the country by being expended on the making of railways and roads.

When he read the paper, he had made a few calculations, so as to ascertain roughly what quantity of oil must have reached the surface before the quantity of pitch now to be found was formed. Taking a very recent estimate, there must be at least 10,000,000

tons of pitch there at the present time. If they took the author's figures of 40 per cent. of bituminous matter in the pitch, that represented about 4,000,000 tons of oil-residue. That was simply a concentrated product or residuum of petroleum which had oozed out from the beds, and represented about 10 per cent. of the original oil, which meant that the product that had gone to form the Pitch Lake was about 40,000,000 tons of oil. As the total oil production of the world in 1906 was 26,000,000 tons, some idea of the immense quantity of oil that had been used in the formation of the lake could be obtained.

He had been especially interested in reading the accounts of the mud volcanoes. In Trinidad he thought that they were the largest of their kind to be found anywhere, except perhaps in Burma, where it would be remembered a few years ago an island of several miles in area was blown up. In Trinidad he had made a measurement of one mud volcano near Princestown, which in a few hours ejected 34,000 cubic yards of material. That was considerably over 35,000 tons.

He had been very fortunate, on visiting the district, to find the Columbia mud volcano in active eruption. Apart from the ejection of mud, there had been many million cubic feet of natural gas wasting into the atmosphere.

With reference to the bitumen, of which the author had spoken a good deal, unfortunately the Trinidad manjak took the form of what was generally known as "pyro-bitumen," or

[redacted]

paper both from a historical and practical point of view. He particularly wished to call attention to the fact that quantities of fire-damp or gas had been found in a manjak mine; and it was equally interesting to place on record that serious quantities of fire-damp had been found in the lead veins of Derbyshire near to where they approached the overlying Yoredale shales, and also in the ironstone mines of Cleveland. In Cleveland, fire-damp occasionally came from the ironstone face where a shot-hole cut through into a break, and sometimes when a fall of roof took place after the removal of the timber in the broken workings. The author had found that the mineral manjak absorbed a certain proportion of oxygen, and it appeared probable that the overlying shales of some of the British coal-seams were undergoing a similar oxidation, and therefore greatly impoverished the available air-current passing into headings or working-faces. The author's test of air taken in a heading revealed 1·6 per cent. of hydrogen in addition to 11·1 per cent. of carburetted hydrogen, which would add very materially to the violence of an explosion; but it was nothing unusual to find a small quantity of hydrogen, carbonic acid, or nitrogen, in what was usually described as carburetted hydrogen or fire-damp.

Mr. S. L. THACKER (Walsall) wrote that the reference to the rate of absorption of oxygen by the manjak was of interest to South Staffordshire mining engineers, in its bearing upon the question of spontaneous combustion. Dr. Haldane and Mr. Meachem had carried out similar experiments on the Thick coal at Hamstead colliery, and had established an apparent relationship between the affinity of a coal for oxygen and its liability to spontaneous combustion.* He would like to know whether, in the experiments on the absorbtive properties of the manjak, any observations were made as to the rise of temperature, and whether any difficulties had arisen in the working of the manjak from gob-fires, in the case either of the amorphous or of the lustrous variety.

It was remarkable that the rapid absorption of oxygen was obtained with the lustrous form of manjak, and it would be of

* "Observations on the Relation of Underground Temperature and Spontaneous Fires in the Coal to Oxidation and to the Causes which Favour it," by Messrs. John S. Haldane and F. G. Meachem, *Trans. Inst. M. E.*, 1899, vol. xvi., page 457.

still further interest if the author could supplement the data supplied with information as to the respective affinities of the lustrous and amorphous varieties.

Mr. JOHN CADMAN (H.M. Inspector of Mines, Newcastle-under-Lyme) said, with reference to the question put by Mr. Binns, that he (Mr. Cadman) had particularly referred in the paper to the quantity of the material and not to the quality. It was so difficult to give any approximate estimate of the quantity that the expenditure of a considerable amount, which was really necessary to develop the mineral, was a serious question. He was obliged to Mr. Binns for pointing out what appeared to be a misleading use of the word "coke." The expression was becoming of more general use, and referred to combustible and not volatile matter.

Mr. G. J. BINNS said that the figure given above was 78 per cent. and below it was 42 per cent.

Mr. CADMAN said that the expression "coke" comprised fixed carbon plus ash, and not volatile matter.

In reply to Mr. Thacker, no observations were made with respect to temperature during the experiments. The lustrous variety absorbed oxygen more rapidly than the amorphous variety, but he (Mr. Cadman) regretted that he was unable to give detailed information on the point. Gob-fires had not, so far as he (Mr. Cadman) was aware, occurred in the working of manjak, but he

[redacted]

CALCINING-KILNS.

BY GREVILLE JONES.

Roasting or calcining ironstone appears to have been practised by early smelters in different forms, for the purpose of getting rid of volatile substances, such as water and carbonic acid, decomposition of iron pyrites, etc., and the transformation of protoxide of iron into peroxide. The forms adopted may be classified under two heads, namely:—(1) Calcining in clamps or mounds in the open air; and (2) calcining in kilns, either coal-fired or gas-fired.

Ores thus treated become porous, and are well adapted for reduction in the blast-furnace. This porosity is decidedly advantageous, as it permits a certain degree of permeation of the gases of the furnace, and thereby exposes a much larger surface of the ore to their action, which renders the work of the blast furnace much easier, as well as being a saving in labour and fuel.

(1) *Calcining in the Open Air.*—As regards the first form, namely, "clamping," this is practised at the present time in Staffordshire and Northamptonshire, the mode of procedure being as follows:—

In the first place, the iron floor-plates are covered with rough ironstone (in order that the plates may not be damaged), then with a layer of coal (preferably lumpy coal) with firewood. Another layer of stone is put on, followed by a layer of coal, the layers of ore increasing in thickness, and the layers of coal decreasing, as the heap increases in height. The heap is then fired at the bottom, and continues to burn until the coal is consumed. Needless to say, this system of calcining ironstone is costly in labour and fuel, and does not always give good results, as some of the ore is but partly calcined or scarred together.

A better method of calcining ironstone in this way is done in some parts where they have a gantry, and is certainly some-

what cheaper in labour. This gantry is an elevated railroad carried on brick pillars or walls, the space between these walls being utilized for calcining the ores; the advantage being that the ironstone is tipped from the trucks (the latter having bottom doors) or, where the works are close to the mines, the stone is tipped direct from the tubs into the space referred to.

(2) *Calcining in Kilns.*—The second form of calcining ironstone is done in the kiln, which is coal-fired; and this practice is in general use in the North of England, being far superior to the first method, inasmuch as less fuel is used, cheaper coal can be utilized, and the calcination of the ironstone is under better control.

The original kilns used, so far as the writer can learn, were of rectangular shape (similar to the old lime-kiln used all over the country), and were built of stone.

The next type of kiln was that introduced by the late Mr. John Gjers, of Middlesbrough (fig. 1, plate xviii.), the casing of which was made of wrought-iron plates riveted together, and lined inside with fire-brick lumps 3 to 4 inches thick by 18 inches long. The bottom of the brickwork rested on a cast-iron lintel-plate, which was supported on cast-iron columns about 2 to 2½ feet high, leaving an open space all round between the bottom of the kiln and the floor. The floor was composed of cast-iron plates about 20 feet in diameter, cast in segments, and carrying in the centre an upright cone. The height of this kiln was 24 feet, the

[redacted]

the kiln, or else by separate columns. Trucks specially designed (hoppered and having bottom-doors) are placed on the gantry, the pins are knocked out, and the stone is automatically tipped into the kiln.

The usual method adopted for working these kilns is as follows:—When starting a new kiln, there is placed, first, to cover the bottom, either calcined ironstone or raw limestone; firewood is then put in and lighted, and coal added. As soon as the fire is well ablaze, a few trucks of ironstone are tipped, and the charging or filling proceeds gradually. A little of the stone is taken out at the bottom, so as to keep the kiln moving, and the operation of filling is continued, according to the way that the kiln works, until it is filled.

There is another type of kiln, the invention of Messrs. Prosser and Upton,* particulars of which are as follows:—The kilns are of square or rectangular, or approximately square or rectangular form, and are supported clear of the ground, preferably on columns, the kilns being made with hopper-bottoms, and with spouts or shoots adapted to discharge the calcined material into cars or trucks that are underneath the kilns. The kilns may be built either in one continuous line, end to end, or in several lines, side by side, without intervening spaces, but it is usually convenient in blast-furnace plant to arrange them in a single line, with a single row of bins along each side. They are lined with brickwork, which is carried by the cross-girders and ledges, formed by joist-girders and plating at the sides of the kiln. The bottom, however, may have a cast-iron lining to protect the shell, and also to form air-ducts or channels between the lining and the bottom-plates or shell, through holes in which air will be admitted to the ducts, and then into the material calcined.

This invention has reference to a construction and arrangement of calcining-kilns, to provide a plant of large capacity, occupying a comparatively small area, and specially arranged for dumping the ore into cars which convey it to the blast-furnace skip or mechanical charging-apparatus. The design of these kilns will be easily understood on reference to figs. 4, 5, and 6 (plate xviii.).

* British patent, 1905, No. 14,571.

Gas-fired Kilns.—The only gas-fired roasters that the writer has seen are those of the Roberts, Davis, and Colby type, which were at the works of the following firms:—North Lebanon Blast Furnaces, Lebanon, Pennsylvania, U.S.A.; Wharton Furnaces, Port Oram, New Jersey, U.S.A.; Messrs. Bolckow, Vaughan, and Company, Limited, Grangetown; and Frodingham Iron and Steel Works, near Doncaster.

At the American works they were roasting magnetic ore, and during this process the sulphur was, to some extent, removed, whilst the magnetite ($Fe_3\,O_4$) was partly transformed into sesquioxide ($Fe_2\,O_3$). With this treatment the ore is more readily reduced in the blast-furnace. Magnetic ore, as is well known, is more difficult to reduce than the hæmatite ores (as they are generally called).

At the North Lebanon works they had in this kiln thirty-two compartments, each compartment capable of dealing with 20 tons of stone in the 24 hours, the kiln being fired by blast-furnace gas.

At the Wharton works the kiln had thirty-six compartments, each compartment supposed to be capable of roasting 35 tons of stone per 24 hours.

These kilns are worked by means of blast-furnace gas, or producer-gas in the event of the furnaces being off. The filling of the kilns is performed in a similar manner to that employed in the Cleveland district.

The capital expenditure on this plant is very high, con-

[redacted]

furnaces, the Roberts, Davis, and Colby kiln is in operation calcining Cleveland ironstone; but the writer has been unable to obtain any reliable information as regards the working of such a kiln in Cleveland. From personal observation, however, he is doubtful (although open to conviction) as to whether this kiln is more economical than the ordinary Cleveland type, for the following reasons, namely:—(1) The calcining plant consists of kilns, exhaust fan, and coal-fired producers (in case of scarcity of blast-furnace gas): therefore, interest and redemption on capital outlay is greater per ton of stone calcined. (2) Labour per ton of stone calcined is higher, as it requires more men to work the abovenamed plant. (3) The ironstone is too hot when leaving the kiln, which is a decided disadvantage so far as a blast-furnace is concerned.

At the works in the United States, where the writer saw the gas-fired kilns in operation, only a single furnace was in blast, and, consequently, the kilns were not working under favourable conditions. Possibly, if these kilns had been working with a number of furnaces, and a sufficient supply of furnace-gas had been available for the kilns, something might be said in favour of them, as regards coal consumption.

It may perhaps be interesting to the members who are not conversant with the working of the roasters, to give an extract from Mr. F. C. Roberts' specification,* as follows:—The object of this invention is to provide a set of ore roasting chambers into which the ore can be dumped from cars evenly, and with the least possible special construction of tracks and furnaces; to arrange the combustion and waste-product chambers so that gas can be fed, and the waste-products carried off by the least possible number of conduits, and to arrange the said roasting-chambers so that not only can cars dump into them, but that cars may carry off the roasted ore with the greatest economy of space and time. The construction of this kiln is shown in figs. 7, 8, and 9 (plate xviii.). Fig. 7 is a vertical cross-section of a Roberts roaster, and shows the same supported by a steel frame, which also supports the transfer-car tracks, the top and bottom chutes, and other accessories. Fig. 8 (plate xviii.) represents a modification of this invention, wherein the chambers are divided into stories by horizontal partitions, and the whole supported on masonry.

* "Improvements in Ore Roasters," British patent, 1902, No. 6,385.

The roasters consist of two sets of chambers, placed side by side, having a space between them, occupied by the stack-flue. Above the furnaces is shown the steel framework supporting the railways, etc. The bin floors are laid on the inclined braces. Each structure is composed of longitudinal walls, divided into chambers (Nos. 1, 2, and 3) by cross-walls. No. 2 pockets (fig. 8, plate xviii.) are the roasting or ore-chambers, having open tops to receive ore from the bins. Their bottoms open inwardly on to the chutes, as shown, and the ore is thus discharged into transfer-cars below. No. 4 is the gas main; No. 1 the combustion-chamber; No. 3 the waste-heat chamber; and No. 5 the stack-flue or pipe, which is connected up to one or more fans, the operation being as follows:—Gas from tube No. 4 meets air drawn through the ports, as shown, combustion ensuing in chamber No. 1; the burning gases pass through the ports on the other side of this chamber into the roasting-chamber, and then into the waste-product chamber; from here they pass into the stack-flue.

It will be seen that this process of roasting is well controlled, because the gas admitted is regulated by valves, and the draught required controlled by the speed of the fan, as well as by the dampers between the connection from the waste-heat chamber and the stack-flue.

The roasters shown in fig. 8 (plate xviii.) are similar in design, except that they are supported on brickwork pillars, [redacted]

separated one from the other by the partition-wall, and divided in their lower parts into ten chambers, each 4½ feet long, by the cross-walls B. The ports on the outer and partition-walls communicate with the atmosphere by the channels indicated, and thus conduct air to the kiln. The roasted ore drops on to cast-iron plates at the bottom, and is there cooled by water from the pipes, C, as shown. The great similarity between this type of kiln and the present-day Roberts, Davis, and Colby type will be noted.

An early roaster heated with blast-furnace gas is shown in figs. 11 and 12 (plate xviii.), and was used at Dannemora. This furnace has proportionately large dimensions, and, as the gas enters the furnace on its periphery, there is a tendency for all the work to be done on the inner wallings, and not to reach the centre of the roaster. An improvement on this type is shown in figs 13, 14, and 15 (plate xviii.), and is in use at Hof, where the gas-tube passes right through the centre of the kiln, and has nozzles, as shown.

In addition to the kilns above described, the writer presents further sections of kilns, which may be of interest, but need no description. Figs. 16 to 29 (plates xviii. and xix.) are early types of kilns which were in use at the Dowlais Ironworks.* Figs. 30 to 38 (plate xix.) are various types of coal-fired kilns in use at the Clarence Ironworks at the present time; fig. 35 being the type of kiln which is now being erected at Clarence in cases of renewals. Figs. 39 and 40 (plate xix.) is a gas-fired kiln which was in use at Clarence in 1864, but unfortunately the writer is unable to obtain any record of its success or otherwise.

The President (Mr. C. E. Rhodes) moved a vote of thanks to Mr. Jones for his interesting paper, which was cordially approved.

Mr. J. B. Tyrrell's paper on "Cobalt and Northern Ontario" was read as follows:—

* *Manufacture of Iron*, by W. Truran, third edition, 1865, plates i. and ii.

COBALT AND NORTHERN ONTARIO.

By J. B. TYRRELL, Mining Engineer, Toronto, Canada.

Situation.—The Province of Ontario lies in the interior of the continent of North America, in the very heart of the temperate zone, between north latitudes 41° 45′ and 52° 15′, or entirely south of the latitude of London. Exclusive of that portion which is covered by the waters of Lakes Ontario, Erie, Huron, and Superior, it has an approximate area of 261,000 square miles.

In its general outline it has somewhat the shape of two triangles joined together near their apices, the base of the smaller or southernmost being formed by the northern shores of Lakes Erie and Ontario and the St. Lawrence river, while the base of the larger or northern triangle is formed by the English and Albany rivers and the southern coast of Hudson Bay. On an average these two base lines lie about 600 miles apart.

The triangles are, however, not even approximately equal in size, the southern being much the smaller of the two, with an area of 54,000 square miles, while the northern has an area [redacted]

province contains 90 per cent. of its total population, and in 1901, the year of the last official census, it yielded farm and garden products of the value of £39,400,000 ($197,000,000), most of which was produced from the southern half of the southern triangle, where the land is underlain by stratified limestones, shales, and sandstones, covered with a thick mantle of drift, and the surface, though well drained, has but very slight relief. Compared with its agricultural wealth, its mineral-production is very small, though in 1906 it yielded petroleum, natural gas, cement, and other non-metallic products of the value of £1,700,000 ($8,500,000).

Geology and Mineral Resources.—The northern half of Old Ontario has a rough rocky surface, underlain by Archæan granites, schists, and marbles which, near the edge of the flat-lying sedimentary rocks to the south, are particularly rugged and bare, for the great glaciers or ice-sheets which moved southward over them during the Glacial Epoch, scraped them clean of most of the decomposed rock and residuary earth which had undoubtedly accumulated on them during preceding ages. This "fall line," or rough edge of the Archæan protaxis, has always served as a great deterrent to settlement in the northern country. In addition, this rocky country is the home of the "white pine" of Canada, and the liability to forest fires has discouraged settlement.

The great triangle of New or Northern Ontario is also known to include vast stretches of rich agricultural land, with an estimated area of 16,000,000 acres; but, as this land is completely surrounded and hemmed in by relatively barren rocky country, as it lies remote from any commercial waterways, and as no railways have yet approached or penetrated it, it has so far remained an untenanted and almost unknown wilderness. In the near future, with the Grand Trunk Pacific railway passing through it from end to end, and the Temiskaming and Northern Ontario railway crossing it from side to side, it will undoubtedly be developed into one of the rich and prosperous agricultural districts of Canada.

At present, mining engineers are interested in the agricultural possibilities of New Ontario, only so far as they affect the progress and development of the mineral industry of that coun-

try. The proximity of fertile land cultivated by a large and thriving community of husbandmen will, of course, greatly assist the mineral industry by providing cheap, abundant, and healthful supplies of provisions for the miners and those dependent on them. Consequently, mining can be carried on under much more favourable conditions than in places where supplies and timber must be transported for long distances at great expense.

Virtually the whole of New Ontario is still covered with a forest of pine, spruce, larch, birch, poplar, and other trees, which in some places grow to large size, while in other places they are small, scattered and of little commercial value. The larger timber is usually found on the drier places, either near the banks of streams, or on the sides and tops of the hills. Under the trees, the ground is usually covered with a dense growth of underbrush. Between the hills the drainage is often imperfect, and extensive mossy swamps cover the bottoms of the valleys, and completely and effectively hide the underlying rock. It may readily be understood that prospecting for the precious metals under such conditions, and in the midst of such surroundings, is a slow and arduous undertaking. Even in the roughest places the surface is generally covered with a layer of soil or humus, and only here and there is the rock exposed to view, probably, on account of its greater hardness, and consequently, unless it should be a vein of quartz, it is not very likely to carry valuable

[redacted]

where provisions, tools, and supplies could readily be obtained, and men could live and work cheaply and comfortably. It is also noticeable that most of these discoveries were not very remote from the accidental ones either in place or time, and were made while the ardour of prospecting engendered by the latter was still a strong compelling force.

The great nickel mines at Sudbury were discovered during the construction of the Canadian Pacific railway, and the silver mines at Cobalt during the construction of the Temiskaming and Northern Ontario railway, while the rock in the hills and ridges was being uncovered and broken, and its mineral contents were being exposed freely and clearly in such a manner as would never have occurred by ordinary natural processes.

In spite, however, of the difficulties of finding and developing its mineral resources, New Ontario is progressing rapidly. In 1906, it yielded metallic products of the approximate value of £3,400,000 ($17,000,000), and in 1907 this sum was increased to £3,800,000 ($19,000,000), derived almost entirely from the two camps mentioned above.

Of these two camps, Sudbury and Cobalt, the latter was the most recently discovered, and has occupied the largest place in the public eye during the past few years. The history of its discovery has often been told, but a very brief outline of the story may bear repeating.

The Government of the Province of Ontario was building a railway northward from the Canadian Pacific railway at North Bay into the more remote northern districts, with the hope of opening to settlement the fertile belt of 16,000,000 acres mentioned above. In the summer of 1903, while the work of construction on this railway was in progress, two of the contractors, Messrs. McKinley and Daragh, discovered some mineral or ore, and staked a mining claim, near the southern end of what is now known as Cobalt Lake. About a month later, Fred LaRose, a French-Canadian blacksmith, working with one of the gangs on the railway, found a vein of smaltite, niccolite, and silver close to his temporary forge, and staked a second mining claim, this time near the northern end of Cobalt Lake, and applied for it on the ground that he had discovered copper-ore, niccolite having apparently been mistaken by him for one of the ores of copper. Later in the same summer two more veins were discovered in the

vicinity. Before the winter set in, these new discoveries were visited by Messrs. T. W. Gibson and W. G. Miller, from the Provincial Bureau of Mines, who at once recognized the character and importance of these veins of smaltite and niccolite with their heavy burden of native silver. They published the news of the occurrence of these rich veins in both the mining and the daily papers, and exhibited specimens of the ore in a number of places, but comparatively little notice was taken of their statements at the time.

The town of Cobalt, the centre of this new camp, is situated 250 miles in a direct line due north of Toronto, the capital of the Province of Ontario, while on the line of travel over the Grand Trunk and Temiskaming and Northern Ontario railways the distance is 330 miles. It lies near the eastern boundary of the province, about half-way between the northern shore of Lake Ontario and the southern shore of Hudson Bay. The surrounding country is drained by tributaries of the Ottawa river, the water from which finally joins the St. Lawrence river at the city of Montreal.

The geology of the Cobalt district, which is exceedingly interesting, has been worked out in considerable detail by the officers of the Geological Survey of Canada and the Bureau of Mines of Ontario, although some features are as yet indefinite and obscure.

The oldest rocks here seen are those to which the name [redacted]

this province, wherever it has been clearly observed, was undoubtedly in a very uneven tumultuous condition. On this uneven surface, Huronian sandstones, clays, and conglomerates were deposited unconformably in a horizontal position, and even now these old sediments, though greatly hardened and metamorphosed, often occupy the same nearly horizontal position, indicating the comparatively small extent of the movements of crumpling and folding to which these rocks have been subjected since they were laid down on the bottom or along the shore of the Huronian ocean.

Subsequent to the deposition of the sandstones and associated sediments, sills of diabase or gabbro were intruded more or less horizontally into them, or between them and the underlying Keewatin greenstones, or sometimes into the greenstones themselves. The exact age of these sills or laccoliths of diabase has not been determined, but they are very much older than the Silurian limestone which underlies parts of adjoining districts, and it is not improbable that they are of the same age as the Keewenawan traps and laccoliths of the Lake Superior region.

The above three series of rocks, all of which frequently resemble one another greatly in general external appearance, together constitute much the larger portion of the rock-floor of the Cobalt district, and are the only rocks in which silver-bearing veins have yet been found to occur, although the veins are by no means equally distributed among them. On Dr. W. G. Miller's recently published map of the Cobalt district, most of the silver-bearing veins in the township of Coleman, which includes the richest parts of the district, are laid down, and there are about 175 in all. Many of these are close to the contacts of the different formations, or they may cross the contacts from one formation into the other; but, in a general way, it may be said that 125 of the veins occur in the Huronian conglomerates, 40 in the Keewatin greenstones, and 10 in the intrusive diabase, some of the latter of which, however, are among the richest in the camp.

The silver-bearing veins occur usually in nearly vertical positions in the rock, and run in all conceivable directions, without any definite orientation. Most of them are narrow, possibly averaging from 2 to 4 inches in width, though some of the notable veins in the camp are two or three times this width, and they even widen in places to 18 or 20 inches.

The gangue is a light-coloured crystalline calcite, and in some veins, such as those of the Kerr Lake mine, the silver occurs as leaves and plates of larger or smaller size scattered irregularly through this gangue. In the majority of the veins, however, smaltite and niccolite (arsenides of cobalt and nickel) are associated with the calcite, and often form connected belts or sheets through it, or they may replace the calcite altogether, and thus compose the whole width of the vein. The smaltite oxidizes into erythrite, the pink arsenate of cobalt; and so common is the association of silver and cobalt that the pink colour or bloom of this latter salt is locally considered to be one of the most important indications of the presence of silver in a vein. In some few places, such as in the Lawson vein, native silver has very largely replaced the arsenides of cobalt and nickel, and in the smoothly glaciated surface shows as a polished mass of white metallic silver for the whole width of the vein.

Associated with the above-mentioned minerals, a number of others have been recognized, and some of them may even play an important part in the value of the ore. Among them are native bismuth, dyscrasite, argentite, pyrargyrite, millerite, cobaltite, chloanthite, annabergite, stromeyerite, argyroperite, etc.

The veins have been formed in well-defined fissures, and their walls are as a rule fairly distinct, so that in mining the vein-matter can be broken down and kept separate from the adjoining [redacted]

probably formed, subsequent to the solidification of the laccoliths, by mineral-bearing solutions which rose from the deeper parts of the barysphere close to the neck or fissure through which the diabase issued, wherever that may have been, and spread out under the mushroom-shaped top of the laccolith, filling the fissures which had been formed, or were forming, in the subjacent rock, whether that rock may have been conglomerate or greenstone. In such a case, these fissures were filled and the veins were formed from above downwards, or from the ends laterally, rather than directly from below as is the case with most normal veins. In the laccolith of diabase itself, such veins as occur were probably formed by the ore-bearing solutions ascending in fissures from its under or lower surface. If any of the veins in the diabase are in the neck through which the molten rock rose from below, they were doubtless formed directly by ascending solutions, and may therefore be confidently expected to continue downwards to greater depths than those formed away from the neck.

Development of the Mines.—In the summer following 1905, prospecting was actively carried on, and many of the principal mines, in addition to those already mentioned, were located, staked, and recorded, including the Trethewey, Coniagas, Buffalo, Drummond, University, Jacob's (now Kerr Lake), and Lawson. Early in the autumn, the rails were laid on the Temiskaming and Northern Ontario railway into the town of Cobalt, and, before the winter set in, 158 tons of ore, taken from small open-cuts on the surface, were shipped to smelters in the United States of America. For these shipments the sum of £27,240 ($136,218) was received, or an average of £172 ($862) per ton.

In 1905, prospecting for new deposits of silver-ore was prosecuted with great activity in the immediate vicinity of Cobalt, and some more rich claims were located. At the same time, ore of high grade was being extracted by surface-workings from many of the veins that had previously been discovered. During that season four mines in all shipped 2,144 tons of ore, which had a value of £295,637 ($1,473,196) or £97 8s. ($487·12) per ton. The spring of 1906 saw continued activity both in prospecting and mining, but the prospectors that year scattered a little farther afield, and discoveries of silver-bearing calcite veins

were made as far away as the townships of Tudhope and James, between 35 and 40 miles north-west of Cobalt. Most of the mines near Cobalt were still open to the surface, but effective machinery began to be installed at some of them; and shafts began to be sunk, and drifts and cross-cuts run, in an orderly and methodical way. During the year the various mines shipped 5,335 tons of ore, valued at £752,822 ($3,764,113) or about £141 ($705) per ton.

During the year 1907, mining was carried on as energetically as in previous years, and twenty-five different mines shipped in all 14,040 tons of ore to various smelters, with value in silver and cobalt of £1,204,130 ($6,020,649), or an average value of about £85 12s. ($428) per ton.

Thus the total quantity of ore shipped from the camp up to December 31st, 1907, was 21,677 tons, with a value of £2,278,835 ($11,394,176), and an average value of about £105 ($525) per ton.

As the veins from which this ore was extracted are mostly narrow, the cost of extraction was undoubtedly high, possibly averaging somewhere in the neighbourhood of £20 ($100) to the ton. This would give £433,540 ($2,167,700) as the total cost of extraction, leaving a profit balance of £1,845,395 ($9,226,476) to be divided among the fortunate owners of the mines. About half of the above profit may be credited to the year 1907. These figures clearly indicate the substantial value of the working mines of the Cobalt camp.

[redacted]

and the transmission to the smelters of spectacular shipments that would average thousands of dollars to the ton, had been considered of much more importance than any economies in mining, or the prevention of losses that might occur through imperfect mining methods.

Saner ideas, however, soon prevailed, and the mine-owners and managers began to count the cost of the work that they had been doing, and to devise plans for greater economy and for more rational systems of developing their mines and treating their ores. While these plans for improvement were under consideration, or were being put into practice, the production of the mines was checked, and this retardation in production was accentuated by a strike of the miners which lasted through some of the best months of the summer. But at the same time shafts were being sunk or deepened, drifts were being run to block out ore, and new and efficient machinery was being installed on every hand, so that by the end of the year many of the mines had a reasonable extent of ore-reserves developed, and were equipped for the extraction and partial treatment of the ore in a rational and economical way. At the end of the year, there were installed at the various mines of the camp boilers of an aggregate capacity of about 8,000 horsepower, thirty-five air-compressors, and between three hundred and four hundred machine-drills.

The management of several of the mines having kindly furnished the author with full information respecting their properties, a few notes as to the equipment and extent of the workings on some of these, as on January 1st, 1908, may serve as types for all.

Right-of-Way Mine.—Ground was broken in the autumn of 1906. Two shafts have been sunk, one 75 and the other 155 feet deep; drifts and cross-cuts have been run, aggregating about 500 feet, and a small amount of stoping has been done. From these workings, ore of the value of somewhat over one-third of a million dollars (about £66,000) has been shipped, while the reserves blocked out above the 65-foot level would probably be worth double that amount. This level is in ore, but below it no reserves have been developed.

The equipment consists of two boilers of 100 horsepower each;

one cross compound-compressor; one $8\frac{1}{4}$ by 10 inches double-drum hoist; one 6-horsepower engine with a 6-kilowatt generator; good shaft and ore-houses; commodious offices; and comfortable quarters for the officials and men.

Cobalt Central Mines.—Ground broken in the autumn of 1906. The deepest shaft is down 225 feet, with drifts at different levels, aggregating in all about 750 feet. No stoping has yet been done. Attention has been given entirely to the work of development. Most of the ore extracted during development has been stored for treatment in the concentrating plant, which has since begun active operations, but 50·68 tons were shipped to one of the smelters. The buildings include shaft, ore-concentrator, and power-houses, as well as offices, laboratory, and quarters for the miners. The equipment is thoroughly up to date. The power is furnished by a water-tube boiler of 225 horsepower. The ore as it comes from the mine is crushed in a Blake crusher and rolls, after which it passes through screens, jigs, and vanners before being shipped in the form of concentrates to the smelters.

Trethewey Silver-cobalt Mine.—This is one of the oldest mines in the camp, and so far has shipped 1,270 tons of ore, most of which was of very high grade, 833 tons having been shipped in 1907. The first car-load of ore shipped from this property weighed 19 tons and sold for £6,800 ($34,000). There is also at the present time about 7,000 tons of low-grade ore on the dump.

[redacted]

lent ore. Power is obtained from boilers with a capacity of 200 horsepower, and air is supplied to the drills from two compressors. In addition to the twenty-five mines which shipped ore to the smelters in 1907, five additional mines shipped ore during the first three months of 1908, and others will undoubtedly soon follow their example. In fact, the Cobalt silver-camp has now assumed its place as one of the important silver producers of the world, although the extent of its ore-bearing veins, either on the surface or in depth, has only been partly and very imperfectly determined.

In the Elk-lake district on the Montreal river, 35 miles northwest of Cobalt, many silver-bearing veins have also been discovered during the past year, and the officials of the Ontario Government are said to have certified to the fact that in about 160 of these veins native silver has been distinctly determinable: an extraordinary circumstance, when it is considered that the country has been travelled over by lumbermen, trappers, and explorers for many years, and that the presence of silver had never even been suspected. It may be considered certain that in not one instance was the silver in evidence in these veins, before they were stripped with pick and shovel of their covering of superficial deposits of clay or sand. This ignorance of the presence of so many mineral-bearing veins in a country so easily accessible may be taken as an instance of the information available as to the possible resources of hundreds of thousands of square miles of territory in Northern Canada, and may give some idea of the work that is yet in store for the prospector.

Conclusion.—It is unsafe to make predictions concerning the future of any mine or group of mines, except such as are based upon the known extent of ore-bodies; but in Cobalt and its vicinity the rational optimists have certainly been reaping the large rewards, and there does not seem to be any sufficient reason why the success that has attended these optimists should now desert them, even if many of them have, in moments of exaltation, capitalized their good fortune in higher figures than they should have done.

Whether the companies that own the mines in the Cobalt district will pay satisfactory dividends on their stock at present market-prices, or not, is beside the question. Many of the mines

have undoubtedly yielded to their owners enormous profits over and above the cost of extraction of the ore, and there is every reason to believe that they will continue to yield large profits in the future.

The PRESIDENT (Mr. C. E. Rhodes) moved a hearty vote of thanks to Mr. Tyrrell for his interesting and instructive paper, and the resolution was unanimously approved.

Mr. C. B. WEDD read the following paper by himself and Mr. G. Cooper Drabble on "The Fluorspar Deposits of Derbyshire":—

[redacted]

THE FLUORSPAR DEPOSITS OF DERBYSHIRE.

BY C. B. WEDD, B.A., F.G.S., OF H.M. GEOLOGICAL SURVEY, AND
G. COOPER DRABBLE.

(*Communicated by permission of the Director of H.M. Geological Survey.*)

PART I.—GEOLOGICAL.

Historical.—Our present knowledge of the distribution of fluorspar in Derbyshire is based upon the mass of carefully authenticated detail published by J. Farey* in 1811 in his comprehensive account of the lead-mines of that county. Gathering his information, with little thought for theoretical considerations, at a time when the ancient industry of lead-mining was still at the height of its prosperity, he has preserved for us a most valuable record of the minerals found in the several veins throughout the Derbyshire lead-district.

J. Pilkington† had previously given a general account of that industry, and had enumerated the places where the different varieties of fluorspar were known to occur; and J. Mawe,‡ classifying these different varieties rather fancifully and chiefly according to colour, had described the mode of occurrence of that known as "Blue John," and its manufacture into vases and other ornaments.

In 1843, W. Adam appended to the third edition of his book a somewhat detailed account of the history and working of fluorspar as an ornamental mineral.§

Mr. A. H. Stokes, H.M. Inspector of Mines, published a short notice of fluorspar and its uses in his paper on the

* *A General View of the Agriculture and Minerals of Derbyshire*, by J. Farey, 1811, vol. i., pages 252 *et seq.*

† *A View of the Present State of Derbyshire*, by J. Pilkington, 1789 (fluorspar, vol. i., page 158).

‡ *The Mineralogy of Derbyshire*, by John Mawe, 1802, pages 69 *et seq.*

§ *The Gem of the Peak: or Matlock Bath and its Vicinity*, by W. Adam, third edition, 1843.

"Economic Geology of Derbyshire,"* and followed this with a general description of the mineral-veins in a later memoir on "Lead and Lead-mining in Derbyshire."†

Dr. A. Strahan, after re-mapping the lead-veins in a part of the Derbyshire limestone-area, summarized previous accounts of the occurrence of fluorspar, figured a section of the fluor-deposit in the "Blue John" mine near Castleton, and embodied in a brief note all that could then be said of the commercial aspect of that mineral.‡

Since then little has been written on Derbyshire fluorspar, except in foreign works on ore-deposits. But some information on the subject is to be found in Mr. F. W. Rudler's handbook:§ and the present authors have lately published a short description of the distribution and economic uses of this spar.‖

Mineralogical Properties of Fluorspar.—Fluorspar or fluorite, by chemical composition calcium fluoride, consisting of 51·28 per cent. of calcium and 48·72 per cent. of fluorine,¶ crystallizes in the cubic system, and, where developed on a free surface, usually shows more or less complete cubes with well-defined angles, sometimes bevelled at the edges. It has a perfect cleavage, a specific gravity of 3·1 to 3·2, and a hardness of 4 on Mohs' scale: that is, while easily scratched with a knife, it is, in comparison with associated minerals, very slightly harder than barytes and blende, and distinctly harder than calcite and galena. A peculiar optical property of its crystals in light has originated

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pink, and pure blue tints met with in other parts of the country; but Mawe records " ruby-coloured fluor in perfect cubes."* Its brighter hues manifest themselves chiefly in the more obviously crystalline forms of superficial crystallization, and in layers or concretions of " Blue John." The more massive commercial fluor of the larger veins is usually of an opaque white, or but faintly tinted. With regard to the colouring-matter of fluorspar, it is interesting to find that so long ago as the beginning of the last century Mawe had anticipated later experiments, for he states that it " has been generally thought to be iron, but I suspect it to be asphalt, which may perhaps contain pyrites in a decomposed state."† G. Wyrouboff, as the result of his experiments on the coloration of fluorspar, concluded that its various colours were attributable to hydrocarbons, on the ground that colour and smell were coincident with the presence of those organic compounds, while colourless and odourless fluorspar contained no hydrocarbons.‡ Dr. W. S. Tangier Smith, however, finding both odour and organic compounds to be present in colourless fluorspar, holds that the actual colour is due to the chemical state of the hydrocarbons, a purple shade, for example, resulting from their oxidation.§

Other Fluorine-minerals.—While fluorspar is by far the most important fluorine-bearing mineral—the only one of any importance in Derbyshire—cryolite, some apatites and tourmalines, most biotites, and the rare mineral fluellite (aluminium-fluoride) all contain fluorine in greater or less proportion.

Stratigraphical Distribution of Fluorspar and Associated Minerals.—In Derbyshire, fluorspar, together with most of the minerals associated with it, is practically confined to the Carboniferous Limestone, though mineral-veins occasionally ascend from the limestone for a short distance into the overlying shales (Limestone Shales).

* *The Mineralogy of Derbyshire*, by John Mawe, 1802, page 76.

† *Ibid.*, page 71.

‡ "Sur les substances colorantes des Fluorines," *Bulletin mensuel de la Société Chimique de Paris*, second series, 1866, vol. v., page 334. See also *Text-book of Descriptive Mineralogy*, by Mr. Hilary Bauerman, 1884, page 378, who expresses the same opinion, on account of the bleaching of dark varieties by heating.

§ "The Lead, Zinc, and Fluorspar Deposits of Western Kentucky," by Messrs. E. O. Ulrich and W. S. Tangier Smith, *United States Geological Survey, Professional Paper No. 36*, 1905, page 126.

While it has long been known that these mineral-veins do not as a rule persist through the sheets of igneous rock (" toadstone ") included in the limestone, though the vein-fissures themselves do,* yet in rare cases these fissures in the toadstone are sufficiently wide to bear mineral-ores. The igneous rocks, owing to their insolubility, and perhaps also to their tendency to fracture less cleanly, and to weather partly into clay, lend themselves much less readily to the formation of open clefts than the limestone does.

Of the minerals associated with fluorspar, lead sometimes occurs in minute quantities in the higher Millstone Grits, and rarely in the Coal-measures; while barytes is frequently met with in the Millstone Grits as a crystalline infilling of narrow joints, somewhat rarely as a cementing material in the Bunter Sandstone, and commonly in the same way in the Keuper Sandstone.

The Carboniferous Limestone and Associated Igneous Rocks.— In order to realize, and as far as possible to understand, the distribution of fluorspar in Derbyshire, it is necessary to consider the structure of the Carboniferous Limestone, a great mass of practically solid limestone, there constituting the lowest known formation of the Carboniferous System, and elevated in a great irregular anticlinal saddle in such a way that neither is its base exposed, nor is it known upon what strata it rests, whether upon a representative of the Old Red Sandstone, or, in the not im-

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only the upper part of the complete thickness of that formation as met with in the south-west of England and in Belgium.

Though we have no certain knowledge of a vast mass of igneous rock in or below the lower and unseen part of the Carboniferous Limestone, yet we have abundant proof of rather widespread igneous activity at more than one period, beneath the limestone-district. For, while the limestone has a superficial extent of somewhere about 200 square miles, more than half of this (roughly speaking, the north-eastern half) may be estimated certainly to contain one or more sheets of igneous rock at or below its present surface. Moreover, neighbouring small inliers of the limestone brought up through the overlying shales on all sides but the north, also contain similar igneous rocks; and one of these inliers occurs on the west side at a distance of 13 miles from the main mass. Hence we may suspect a widespread igneous magma as a source of eruptive activity beneath the district. The igneous rocks, studied in recent times chiefly by Sir Archibald Geikie* and Dr. H. H. Arnold-Bemrose,† are all basic in composition, and show at least five different habits, (*a*) lava-flows and (*b*) ashes or tuffs, both contemporaneous with the limestone; (*c*) masses of igneous and calcareous agglomerate, regarded with some reason in certain cases as volcanic necks; (*d*) intrusive sheets or sills, and very rarely (*e*) dykes or vertical fissures filled with igneous material, the last two necessarily younger (perhaps very much younger) than the limestone and its contemporaneous volcanic rocks.

Of these rocks individual lava-sheets may extend from their outcrop throughout an area of many square miles, and may attain a thickness of more than 100 feet, while sills of less extent may be thicker.

Two extensive lava-sheets are known in the northern part of the limestone-area and two in the south-eastern. In the latter region there is a sheet of lava about 150 feet below the stratigraphical top of the limestone—in the Ashover inlier a volcanic ash occupies about the same position‡—and another lava, about

* *Ancient Volcanoes of Great Britain*, by Sir Archibald Geikie, 1897, vol. ii., pages 8 *et seq.*

† "The Toadstones of Derbyshire: their Field-relations and Petrography," by Dr. H. H. Arnold-Bemrose, *Quarterly Journal of the Geological Society*, 1907, vol. lxiii., page 241.

‡ *Ibid.*, page 266.

150 feet lower, extends as far as the Crich inlier.* An intrusive sill† at Bonsall is met with at a maximum distance of 300 feet lower, that is, beneath 600 feet of limestone at the most. In the northern region a local bed of volcanic ash‡ lies more than 125 feet below the top of the limestone, and two wide-spreading lavas respectively about 520 feet§ and about 700 feet‖ down in the limestone; while at Peak Forest an intrusive sill of little extent and apparently the lowest-known igneous sheet in Derbyshire, occurs at a horizon probably about 900 feet down in the limestone. Thus all the known igneous sheets are found, roughly speaking, in the upper half of the ascertained thickness of limestone, the highest of them in the south-east of the limestone-tract, only about 150 feet below the top.

Besides these igneous rocks, there are occasional thin bands of shale, never more than a very few feet thick, chiefly in the highest beds, but also at rare intervals down to a depth of at least 400 or 500 feet in the limestone. The sheets of igneous rock and the shale-bands are alike relatively impervious to water.

The topmost beds of the limestone show, moreover, an abundant development of silica in the form of chert. This is confined to the uppermost 50 or 60 feet of the limestone in the south-east of the district; but farther north and on the west side chert develops downward in the limestone, until it affects at least 400 feet of strata. There is, moreover, a widespread, but sparse, growth of microscopic crystals of secondary quartz; and this,

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The pure limestone frequently gives place to a more or less completely dolomitic rock, which, often extremely irregular in its development, may locally involve thick beds of the series for a considerable distance, as at Matlock Bath and northward of Hopton and Brassington.

Lastly, the highest beds of the limestone—the uppermost 300 feet in the south-east, and apparently a greater thickness in the north and west—are very much more fossiliferous than the remainder, and hence may be expected to contain more products of organic matter. These manifest themselves in the form of petroleum, of which the cavities of shells sometimes enclose an appreciable quantity; elaterite and bitumen also are frequently found in shells and corals. The fossiliferous nature of the limestone diminishes somewhat rapidly downwards. The fossils consist of vast quantities of brachiopods, chiefly *Productus*, often making great shell-beds, and of equally vast quantities of crinoids and masses of corals.

Structure of the Limestone-area.—The irregular saddle into which earth-movements have thrown the Carboniferous Limestone with its contemporaneous volcanic rocks, is in itself an accentuation of the southern end of the anticlinal Pennine Chain, and is elongated in a general north-and-south direction. In it the limestone passes on all sides under the overlying shales. In the northern half of the limestone-area the main axis of elevation lies comparatively close to the western margin; so that, on the whole, the strata dip steeply towards the west and much more gently towards the east. In the southern part this principal axis appears to divide into at least two branches, one trending east-south-eastwards to Matlock and Wirksworth, the other south-south-westwards. Marginal faults in several places diminish the distance between the crest of the saddle and the western boundary of the limestone, by cutting off some part of the latter at the surface. But minor folds or undulations destroy the simplicity of the structure, so that the dip rarely remains constant for long distances.

It will appear later that this structure has an important bearing on the distribution of the minerals contained in the limestone. From it, and from the ordinary effects of atmospheric denudation, it results that in a general way the highest strata of limestone are confined to the margins of the area; that they

have, for the most part, a much wider superficial extent on the east side than on the west, and that lower beds are brought to the surface in the central area.

Similarly the limestone-inliers of Crich and Ashover, situated respectively 2½ and 3 miles east of the main mass, lie upon a long, narrow, and sinuous anticline at the two points of its greatest elevation.*

Minerals Associated with Fluorspar.—In Derbyshire, fluorspar is usually found in association with a definite group of other minerals. The chief of these are barytes; calcite; lead, mainly in the form of slightly argentiferous galena, but sometimes as cerussite; zinc, as blende or calamine; and locally copper. It is noteworthy that these minerals, with the addition of quartz, are frequently associated in different parts of the world, especially in calcareous rocks.

Mode of Occurrence.—In the Derbyshire limestone, the mineral-deposits occur principally as the filling or lining of fissures and other cavities. The several forms of deposit have generally been classified as Rakes or Rake-veins, Pipes, and Flats;† and this classification has obtained wide currency in geological literature. But it scarcely represents accurately the general mode of occurrence, for "flats" that are independent of "rakes," and do not come under the definition of "pipes," are rare; while a common class of mineralized cavities is conveni-[redacted]

one or more horizontal cavities formed along the bedding, the whole being more or less completely infilled with mineral-ore.

(*d*) Flats: deposits in horizontal cavities formed along the bedding and regarded independently of "pipes."

The Rake-veins.—Scrins and rake-veins range from mere cracks to enlarged joints or fault-fissures, commonly as much as 5 or 6 feet wide and occasionally attaining a width of 30 or 40 feet in places. The larger veins are variously filled with mineral-deposits in crusts on both walls. The gangue of a vein may consist entirely of fluorspar, which may more or less completely fill the fissure for a considerable part of its vertical range. Or it may consist of calcite or barytes, or of any combination of the three minerals, in alternate layers. Usually, however, it will contain one or more layers and frequent small inclusions of lead-ore; sometimes also of zinc-ore. The lead-ore may alternate with the other minerals, or may form a central string. Local variations of width or of amount of mineral-deposition may cause some parts of the cavity to be filled, while other parts are not, so that lenticular spaces may be left. The same manner of partial or complete infilling applies to other mineralized cavities.

Frequently the veins run vertically, or nearly so, but when they hade or incline, there is a strong tendency towards greater deposition of all minerals on the hanging wall. The veins may branch, or they may enclose large slices of the country-rock or detached fragments.

Only on free surfaces of incompletely filled cavities do we find the minerals developed in perfect crystalline form. In the case of fluorspar there is rarely, if ever, so large a growth of individual crystals, as sometimes elsewhere.

The usually sharp demarcation of the fissure-walls, and the frequency of "slickensiding," unmistakably due to movement and friction, show that the rakes are true fissure-veins.

But sometimes the rock-wall may exhibit a distinct metasomatic replacement or impregnation with fluorite or galena, or other minerals, for a very short distance inwards; and it is probable that a local metasomatic replacement of the limestone by the minerals usually found in cavities may here and there have taken place on a larger scale.

Of the nature of the fissures in which the rake-veins occur, Dr. Strahan states:—

> "The rake is usually a nearly vertical fissure, resulting apparently from the widening of a joint in the limestone by the solvent action of water. The walls, however, not infrequently show slickensides, running horizontally or vertically or at any intermediate angle, while the strata are found to have suffered displacement, so that the same bed occurs at different levels on opposite sides of the rake, this displacement varying in different veins from an inch or two to many yards. Where the displacement is considerable, the vein usually hades or underlies (slopes) in the direction of the downthrow, and is in short not to be distinguished from an ordinary fault except in the commercial value of its contents. The greater number of the Derbyshire rakes, however, are merely vertical cracks, running for a limited distance either across country or downwards." *

A vein-fissure often widens very considerably in its highest part, mineralized in the same manner as the rest of the fissure, but sometimes containing riders or detached wedges of the country-rock. This widening takes place chiefly, if not exclusively in the very highest beds of the limestone, except in possible instances of the accidental truncation of a pipe or pocket by denudation. The Great Hucklow Edge Rake affords an extreme case in the highest limestone-strata (see page 514). Obviously, the widening in such cases preceded the mineralization of the fissure.

Neither in the fluor-veins nor, so far as the authors know, in those bearing other minerals, is there limitation to any particular trend or set of fissures. The fault-fissures and joints run in several directions, an approximately east-and-west strike being [redacted]

show that movement recurred at intervals along old lines of fracture. We have this evidence, in fact, in some of the Derbyshire veins. Again, we find an intrusive sill of igneous rock at Bonsall, sheared by movements in the neighbourhood and direction of north-westerly fractures, themselves heavily mineralized. Hence we can assume that the ore-deposits were introduced subsequently to the folding of the strata, and perhaps later than the intrusion of the igneous sills.

Great difficulty attends any attempt to determine the order of deposition of the several minerals in the veins, a difficulty experienced by students of mineral-veins in other parts of the world. Messrs. Fuchs and De Launay state that barytes and fluorspar were generally deposited first in the Derbyshire veins, and were followed by galena.* In the case of the very similar veins in the Lower Carboniferous (Mississippian) rocks of Western Kentucky, Messrs. Ulrich and Tangier Smith, while fully recognizing the difficulty, have shown that in several instances fluorspar was deposited either first or contemporaneously with barytes, calcite, or galena, and that quartz (absent from the Derbyshire veins) usually formed last.† The authors believe that no constant order can be determined. But fluorspar was certainly very often, calcite sometimes, the first mineral to be deposited on the walls of a vein. If we may assume fluctuations of hydrostatic level in an aqueous solution of minerals, having different specific gravities, or otherwise differentiated, in vein-fissures, a reason for the difficulty becomes apparent. As an illustration, both of the difficulty and of a typical mineral-vein, the authors give here the results of their examination of the Great Rake (No. 22, plate xx.; see also page 516) at Matlock Bath.

This vein crops out as the higher of two nearly parallel rakes, whose fissures mark the upper and lower limits of a sharp downward bend in the southern flank of the anticline of High Tor and Masson Hill. It is nearly vertical, but has a slight and irregular hade, northerly near the river, southerly a short distance east of it. In one place a transverse section of the fissure shows a distinct sigmoidal curve in the upper part of the vein. Both walls have

* *Traité des Gîtes Minéraux et Métallifères*, by Messrs. E. Fuchs and L. de Launay, 1893, vol. ii., page 617.

† "The Lead, Zinc, and Fluorspar Deposits of Western Kentucky," by Messrs. E. O. Ulrich and W. S. Tangier Smith, *United States Geological Survey, Professional Paper No. 36*, 1905, page 141.

strong slickensiding in a nearly horizontal direction, and where east of the river the rake enters the cherty limestone, both the limestone and the included chert-masses are equally slickensided, the latter bulging forward very slightly. Slickensiding is seen also in the vein-minerals, both close to and several inches from each wall, and also in the middle of the vein west of the river. Hence movement took place both before and after the deposition of the greater part of the mineral-contents. In most places in the superficial part of the vein fluorspar formed directly upon both walls; in one place was a thin crust of cubical crystals on a slickensided surface of the hanging north wall; while a little further east and a few feet lower calcite had crystallized upon the slickensided surface of the same wall, itself metasomatically impregnated with fluor and galena. West of the river, on the southern wall thin alternations of fluor and calcite were seen, ranging from $\frac{1}{10}$ inch to $\frac{1}{3}$ inch in thickness. Elsewhere, east of the river, a little scrin of calcite was found to run just behind the wall-face, the latter coated with fluor in the same neighbourhood. Again, a scrin of fluor had almost isolated a " rider " of the limestone-wall, covered with a massive deposit of fluor. The bulk of the vein evidently consisted of fluorspar with strings of galena.

The miners have a saying that lead is found wherever fluorspar occurs. It will appear subsequently that the converse of this does not hold.

Absence of Quartz.—The practically complete absence of [redacted]

Mine, Masson Hill, Matlock Bath, in the neighbourhood of the most remarkable development of secondary "quartz-rock" in the Derbyshire limestone, has lately been made for one of the authors by Dr. G. Tate, of Liverpool, and confirms this expectation:—

ANALYSIS OF "LUMP-SPAR" FROM THE HIGH LOFT MINE, MATLOCK BATH.

	Per cent.
Calcium fluoride (CaF_2)	98·5
Calcium carbonate ($CaCO_3$)	0·5
Barytes ($BaSO_4$)	absent
Sulphur as sulphide	absent
Silica (SiO_2)	0·1
Lead	—
Zinc	—
Total	99·1

The authors believe, however, that in some cases the amount of silica in Derbyshire "lump-spar" may reach as much as 1 per cent. But it appears that the fluorspar of Derbyshire is remarkably free from silica.

Distribution of Fluorspar in the Limestone-area: Fluor-producing Districts.—In the following brief descriptions of the veins, the fluor-bearing districts are dealt with in geographical order, from the northern limit of the limestone-tract southwards. Where fluor occurs as the gangue in appreciable quantities, the veins are shown by thick lines on the accompanying map. The districts naturally group themselves into six, namely: (*a*) Bradwell; (*b*) Eyam and Stony Middleton; (*c*) Longstone Edge and Hassop; (*d*) Ashover; (*e*) Matlock; and (*f*) Crich. The fluor-veins are numbered on the map (plate xx.) to facilitate reference: those that are actually being worked at the present time are noted in the text.

Description of Veins and Pipes: The Bradwell District.—About a mile west of Castleton is the Treak Cliff Mine (No. 1), reputedly discovered by the Romans. It has long been famous for its "Blue John," which occurs as a lining on the walls of the "pipes" in the vein. Nodular concretions are also found mixed with barytes in clay. The quantity raised has of late years rapidly diminished, and this mine is the only source of supply, although Farey mentions "Blue John" as found also at Crich and Cromford. South-west of Castleton a vein (No. 2) is being

worked for both lead and fluor, which occur here principally in small "flats."

The Smalldale-head vein (No. 3) lies to the north of Bradwell and is yielding a yellow fluor.

Near Hazlebadge Hall a pipe (No. 4) containing yellow fluor, seems to be connected with the eastern end of the Shuttle Rake.

In the Shuttle Rake (No. 5) the gangue is mainly calcite west of the Castleton road, and fluor with barytes east of the same point; the vein is worked at the Shuttle and Intake-dale Mines.

The Nether-water vein (No. 6) is a small rake with clear white fluor.

The Virgin (No. 7) also has a gangue of white fluor with occasional tinges of blue. This vein is at present watered.

The whole of the above veins range about 10 degrees west to 15 degrees south, and the depth to the toadstone varies from 288 to 312 feet.

Eyam District.—The master-vein of this district, the Great Hucklow Edge Rake (No. 8), is one of the strongest rakes in Derbyshire. It traverses the measures a distance of 7 miles, has been largely worked, and carries calcite with carbonate of lead in the west, where the limestone is exposed, but fluor with galena in its eastern range, where the limestone lies under a cover of 792 feet of grit and shales. The vein is in places 150 feet wide at the surface, but narrows to 30 or 36 feet at 360 feet down in the limestone. Some of the principal mines on it are [redacted]

eastern range as the High Rake (No. 16), and as the Deep Rake (No. 15). It is upwards of 14 yards in width, and is being largely worked at the Sallet Hole Sough (No. 13) and by levels driven from the valley at the eastern end of the vein; the Red Rake (No. 14) is a branch from the Deep Rake and is worked by the North-Cliff level (No. 20). These mines are now producing much fluor with galena.

The Ox-pasture vein (No. 17) and the Crossdale-head vein (No. 18) branch from the western end of the High Rake, the second (No. 18) joining the Hard Rake (No. 19) to the east. Fluor is most abundant at the eastern end of these. The foregoing veins have been worked at the Brightside, Harrybecca, Backdale, Crossdale, Ox-pasture, and other mines from 340 to 360 feet down in the limestone. The Backdale Sough, driven from Calver Mill, a distance of about 1¼ miles, unwaters most of this ground.

It is perhaps worthy of note that the south-easterly dip of the measures at the eastern end of these veins increases from about 10 degrees on the high ground to 45 degrees as the shales are approached.

In the western range of the master-vein the gangue is almost wholly calcite; near the middle it is calcite and barytes; near the High Rake barytes and fluor; and, finally, fluor almost exclusively in the eastern range.

Ashover Inlier.—The principal veins are the Gregory (No. 30), the Fall-hill (No. 29), the Overton (No. 28), the Westedge (No. 33), and the Stars Wood (No. 31), with a number of smaller rakes or scrins, nearly all of which contain fluor in greater or less quantities.

Fluor is consistently strong in all the larger veins, though associated with a little calcite in some cases. It is being got in the Gregory, Overton and Fall-hill veins.

Matlock District.—The fluor-bearing veins in this district appear to be rather more irregular and scattered than elsewhere. The Ox-close Pipe (No. 21) at Snitterton yields a clear white fluor associated with pyrites.

The High Loft (Knowles) Mine (No. 23) on Masson, where the fluor raised is of a delicate heliotrope colour, is a pipe probably connected with the Great Rake.

The Great Rake (No. 22) crosses the dale near the southern end of the High Tor and ranges south of west towards Bonsall. The fluor in the upper measures is hard and crystalline, but below the lower lava becomes granular—notably in Smith's Mine above Bonsall, where it is now being raised.

The Mole-trap Lode (No. 27) near Cromford, contains a hard white fluor with blende. The vein is about 10 feet wide in its eastern range under the shale.

At the Coal-pit Rake (No. 25) the fluor is associated with calcite in its western range, and becomes more abundant eastwards as the shale-covering is approached.

A vein (No. 24) in the High Tor contains a clear white crystalline fluor.

Crich Inlier.—The principal veins here are The Glory (No. 33), The Church (No. 35), Hard Rake (No. 34), Plaistowfield (a branch from the Glory), Bacchus Pipe, and Pearson's Venture (No. 36).

The Glory is worked at the Glory and Old End mines, and a level is being driven from the stream at the western end of the vein. At the Bacchus Pipe and Pearson's Venture work is proceeding. Fluor appears to be confined here almost exclusively to the limestone-measures above the toadstone, which occurs from 300 to 360 feet below the surface. Below the toadstone the gangue consists largely of calcite. These mines are unwatered down to 420 feet by the Fritchley and Ridgway Soughs.

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A small quantity of fluorspar is associated with galena at the Ecton copper-mine on the west side of the Derbyshire limestone, where Mawe states that it is "water-coloured or light blue.*

That the quantity was insufficient for economic purposes is indicated by Farey's statement that in 1800 a large amount of fluorspar from the High Loft or Knowles Mine at Matlock was sent to Ecton for copper-smelting.†

The authors have no knowledge of the presence of fluorspar in any other part of the limestone-area. Now, for many centuries this area has been thoroughly explored for lead: Farey made an exhaustive examination of the mineral-contents of the mines; and it is on record that fluorspar was commonly recognized and used for fluxing as early as 1730 (see page 527); moreover, recent examination of the old workings and "hillocks" has failed to show any evidence of fluorspar outside the districts mentioned above. Hence we have some reason to suppose that this mineral is limited to that part of the limestone-sequence in which it is known to occur. Thus we find that fluorspar is entirely confined to the marginal parts of the main limestone-area, and to the neighbouring inliers of limestone east of it; and, moreover, that with the single exception of its presence in very small quantity at Ecton on the western margin, it is only found to occur on the eastern margin of the main mass of limestone.

Vertical Range of Fluorspar in the Limestone.—A consideration of the anticlinal structure of the limestone-mass suggests at once the limitation of fluorspar to those parts of the rakes and pipes that traverse the highest strata of the limestone series; and an examination of the mineral-deposits in relation to the limestone which contains them, confirms this view. The authors believe, in fact, that fluorspar in the Derbyshire limestone-area is confined to the uppermost 550 or, at the most, 600 feet of that limestone; and that it is chiefly concentrated in the uppermost 300 or 400 feet. This view will now be examined in detail, and the known range of fluorspar in each district considered.

* *The Mineralogy of Derbyshire*, by John Mawe, 1802, page 110.

† *A General View of the Agriculture and Minerals of Derbyshire; drawn up for the Consideration of the Board of Agriculture*, by J. Farey, 1811, vol. i., page 461.

In the Bradwell district it is evident from the strike of the upper lava—itself about 520 feet down in the limestone—and its relation to the anticlinal structure of the ground, that both the "Blue John" mine (No. 1, plate xx.), near Castleton, and the vein (No. 2) south of it reach the surface in a position above that lava, down to which neither of them has been worked. In the case of the Shuttle Rake* (No. 5), in which a gangue of fluorspar gives place westward to calcite beyond the Castleton road, the fluor-bearing part of the vein extends farther west and consequently into lower strata than in the case of the neighbouring veins. Thus, all these rakes cease to bear fluorspar for a considerable distance before they reach the outcrop of the upper lava.

In the Eyam district the Great Hucklow Edge Rake (No. 8) affords another example of an extensive vein bearing fluorspar only in its eastern part, that is, in the highest beds of the limestone. Mining operations have not extended below the highest toadstone, which must there be the upper lava, if it be not a local bed of volcanic ash, which crops out farther west at an uncertain distance above that lava.

Again, in the Longtsone-Edge district the veins become rich in fluor only at their eastern end: several of these have been worked to a depth of 360 feet, while on the Deep Rake (No. 15) a toadstone, probably the upper lava, was reached at 420 feet.

In the Matlock district fluorspar occurs chiefly above the [redacted]

highest beds of the limestone, but to a great depth. It may reasonably be expected, however, on analogy, that the fluorspar there belongs to the upper strata.

In the Ashover inlier mining has not extended below the toadstone (volcanic ash), which lies at, or a little below, the horizon of the upper lava of the south-eastern region. That is to say, fluorspar and lead are obtained only from the uppermost 150 or 180 feet of the limestone.

The Crich inlier furnishes important evidence. The lead-mines have worked through the toadstone, there probably the lower lava of the south-east, beneath 300 feet of limestone. Lead is usually richest about 70 feet below the toadstone, above which the veins are very rich in fluorspar, which often composes the whole gangue. But below the toadstone fluorspar scarcely occurs. A dissection of the "hillock" at the Old End Mine showed an upper and outer layer containing about 90 per cent. of calcite in the waste-material from the lower part of the shaft, a middle layer of toadstone-débris, and an inner core consisting of about 90 per cent. of fluorspar. The Old End Mine was sunk to a depth of nearly 1,000 feet: that is, after subtracting the thickness of toadstone, nearly 600 feet below the latter, in lead-bearing deposits with little or no fluorspar. An examination of the "hillocks" of the Wakebridge and Glory Mines gave indications of a similar result. It seems probable that, throughout the Crich inlier, fluorspar is practically confined to the 300 feet of limestone above the toadstone.

There are, then, good grounds for believing that, at any rate, in the limestone cropping out at the surface in Derbyshire, fluorspar is limited to the uppermost strata as defined above. And it is seen that the general anticlinal structure of the limestone-mass, coupled with the effects of denudation, has a very important bearing on the distribution of fluorspar, in that it brings to the surface in the interior of the limestone-area beds in which the veins appear not to contain that mineral; while it narrowly limits the zone of fluor-bearing strata on the east side and much further reduces the belt in which these beds could crop out on the west side in the northern half of the area. This, of course, follows from the approximation of the axis of greatest elevation to the western margin and the frequency of marginal faulting on that side.

Now, there is some reason to believe that fluorspar increases in strength as it is traced eastwards in the limestone under the overlying shales; and it is necessary to bear in mind a possibility that we may have here the south-western border of a richer fluor-bearing province. In view of this possibility, interest attaches to the absence of fluor and barytes from the lead- and zinc-veins of Flintshire,* and the apparent absence of fluorspar from certain parts of the Derbyshire limestone-area, where the highest beds are well developed, notably in the south-west. It is quite likely that some such circumstance has modified the simple effect of folding and denudation upon a vertically restricted range of fluorspar.

But the strong evidence that this mineral dies out directly downwards in the Crich inlier—itself eastward of the main limestone—lends much support to the view that its restriction to the highest beds of the limestone is mainly responsible for its limited distribution in the limestone-area; and this view receives further support from the well-known fact that the lead-veins become impoverished in depth.† Indeed, there is very little lead in the lower strata of the Derbyshire limestone.

The distribution of the fluor-districts in the limestone-area brings out another point, definite enough, but of doubtful interpretation, namely, a strong tendency towards the location of these fluor-districts upon anticlinal curves of the limestone. This is noticeable in all cases, but least distinct in the districts [redacted]

tion. The phenomenon is of too doubtful significance for more than a cursory notice.

The authors conclude, then, that within the area of the limestone-outcrop, fluorspar, as a vein-mineral and to a small extent as a metasomatic replacement of the country-rock, is restricted to the uppermost 550 or 600 feet of the limestone, and is mainly concentrated in the uppermost 300 or 400 feet: further, that this restriction is chiefly the effect of failure of the fluorspar in a vertical downward direction; but that it may possibly be influenced by accidental coincidence of the eastern margin of the limestone-area with the margin of a more productive fluor-province, in which the same restriction of vertical range cannot be assumed to apply; and that fluorspar is not everywhere present in the highest beds of the limestone.

Certain other conclusions necessarily follow, namely, that the fluor-bearing limestone is always wholly above the lowest sheet of igneous rock in each district, and that a large proportion, usually the greater part, of the fluorspar lies above the highest igneous sheet; that the main development* of cherty limestone is wholly comprised in the strata containing the fluor-bearing veins; and that the latter strata form by far the most fossiliferous part of the limestone-series.

There is, moreover, reason to believe that fluorspar is not present in great quantity in the more highly dolomitic parts of the limestone.

Views on the Origin and Manner of Formation of Mineral-deposits.—The highly controversial question of the origin of mineral-deposits has engaged the attention of geologists and mining engineers from the earliest days of scientific research, and around it a large literature has grown up in recent years. The divergence of opinion in the case of such deposits as are here under consideration, relates chiefly to the source of the mineral-matter, whether from above, from the country-rock containing the mineral-deposits, or from below; and in less degree to the manner of introduction, whether in the form of gas or vapour by sublimation, or in solution in more or less heated water containing gases.

As for the manner of introduction, in the case of regions like

* There are rare and scanty local developments of chert at lower horizons.

Derbyshire, practically devoid of metamorphism, a general preponderance of opinion obtains in favour of aqueous solution.

As to the source of the mineral-matter there is more discordance of opinion, though probably the balance tells in favour of origin from below in connexion with deep-seated igneous action; and in this connexion there exists a somewhat widespread belief in the association of such mineral-deposits in sedimentary rocks with the presence of igneous rocks and especially dykes. The filling of mineral-veins by infiltration from above, first advocated by Werner,* finds few supporters nowadays as a general principle. Mr. S. F. Emmons considers the lead-ores of Leadville, Colorado, to have been derived immediately from the overlying "white porphyry" by infiltration and metasomatic replacement of the dolomitic limestone below.† But Prof. R. Beck states that "true mineral-veins formed by solutions bringing material from above are probably very rare."‡

Owing to the presence of calcium-fluoride in minute quantities in shells, in corals, and in the bones and teeth of vertebrates, as well as in sea-water, the view of lateral secretion, by percolation of ground-waters dissolving out mineral-matters from the country-rock and re-depositing them in veins, was urged by Bischof and Forchhammer, and was supported by W. Wallace in the case of the mineral-veins of Alston Moor.§ F. Sandberger sought to prove the formation of the lead- and silver-veins of Przibram by lateral secretion from accompanying diabases.‖ [redacted]

Dr. W. S. Tangier Smith has applied a modification of this view to the case of the mineral-veins of Western Kentucky, considering the minerals to have ascended in solution along fault-fissures, but to have originated in a much lower limestone. He admits, however, the possibility of their derivation from the deep-seated magma of the numerous basic dykes of that district.*

Now, the circumstances of these mineral-veins are very similar to those of the Derbyshire veins, as was pointed out by D. D. Owen† in 1856, but with certain important differences. In Western Kentucky and Southern Illinois the veins occur in alternations of thick limestones with thick quartzites, sandstones, and shales of Mississippian (Lower Carboniferous) age. But there numerous large fault-fissures are filled, sometimes with veins of fluorspar and the minerals usually associated with it, sometimes with basic dykes (peridotite); whereas in other parts of the Mississippi basin similar veins contain no fluorspar, and the dykes are absent. In Derbyshire, dykes are very rare, being confined to three or four of small extent in the immediate neighbourhood of other intrusive rocks (unless other dykes fail to reach the surface), while the veins do not usually lie in large fault-fissures.

From the point of view of deposition by ascending solutions, the ancient mines of Laurium, in Attica, furnish a very interesting example as interpreted by Huet, whose view is accepted by Messrs. Fuchs and De Launay. In a triple succession of thick limestones, overlain by thick shale, the whole metamorphosed and intersected by strongly-hading eurite-dykes, the minerals, including argentiferous galena and blende, are deposited in the upper parts of the limestones and under the foot-walls of the dykes where they traverse the limestones. The mineral-deposits diminish upwards in richness in each successive limestone, and are poor in the highest, in which alone fluorspar is mentioned as a constituent. Huet's view is, that a mineral-solution rising from below in fissures was arrested by a " lid " of shale or eurite, and dissolving the limestone beneath formed the deposits by incrustation and metasomatic replacement: that it rose further through narrow crevices in the insoluble shales and dykes with-

* Dr. W. S. Tangier Smith in "The Lead, Zinc, and Fluorspar Deposits of Western Kentucky," *United States Geological Survey, Professional Paper No. 36*, 1905, page 151.

† *Report of the Geological Survey in Kentucky, made during the Years 1854 and 1855*, by D. D. Owen, page 86.

out any deposition, and in an increasingly impoverished state repeated the process of deposition in the upper part of each higher limestone.*

Considering the lack of unanimity of opinion as to the source and manner of formation of such mineral-deposits, and the necessity of regarding those of Derbyshire, not as an isolated phenomenon, but as a single manifestation of a general phenomenon, the authors disclaim any attempt to settle this question for Derbyshire independently. They wish, however, briefly to point out such facts as seem to have a bearing upon the question, and merely suggest what appears to be the most reasonable hypothesis in accordance with ascertained circumstances in that district.

The practically complete absence of quartz from the veins and the very low percentage of silica in the "lump-spar"—facts of economic importance as well as of theoretical interest in veins traversing a limestone that contains both chert and (sometimes) secondary quartz in large quantities—are difficult to reconcile with any other view than that of derivation from a source external to the country rock in which the veins occur.

The limitation of fluorspar to the highest part of the limestone within the area of its outcrop is consistent with any one of the three views of the source of mineral-matter; but only with that of lateral secretion from the country rock, on the assumption that excess of organic matter in the more fossiliferous upper lime-

[redacted]

temperature before they reached the relatively insoluble igneous rocks. But nothing in the association of fluorspar with sheets of basic igneous rock in the same district is inconsistent with an ultimate origin of both from the same source. However, in the general absence of dykes and in the usual occurrence of the Derbyshire mineral-deposits in fissures other than those produced by powerful faulting, the authors fail to find such facility of communication with deep-seated regions as is held to be an important factor in other cases of similar mineral-veins. Neither does the local presence of warm springs, either by the temperature and mineral-contents of their waters, or by their distribution, obviously indicate a common source with the solutions that filled the veins; but it may possibly suggest a continuance of like conditions.

On the whole, the authors believe that local circumstances in Derbyshire agree best with the hypothesis of deposition, in fissures and to a small extent as a metasomatic replacement of the country-rock, from a heated aqueous solution containing gases and forced up from a great depth, possibly in connexion with the later phase of igneous activity: that deposition, consequent on diminution of pressure and temperature, was precluded in the case of fluorspar from taking place in the lower parts of the vein-fissures owing to the decomposition of that mineral by superheated steam;* and that its relatively low specific gravity probably had some further influence in determining the limitation of fluorspar to the upper parts of the fissures. The greater liability of the fluor-bearing parts of the veins to the effects of infiltration, both of sulphides from the overlying shales and of organic products from the most fossiliferous strata of the country rock, should be noted, although it may be merely fortuitous. But it is extremely probable that in any case the waters of the vadose circulation, carrying in solution mineral-matter picked up in their course, produced some slight effect in remodelling or in adding to the original mineralization. Such waters must necessarily have dissolved a large amount of calcium-carbonate, and very frequently calcite-crystals formed upon fluorspar and other minerals are found in the veins. The common development of calcareous stalactites is, of course, proof of the later and still-continuing introduction of some mineral-matter into mineralized cavities.

* The authors are indebted to Dr. W. Pollard for the information that superheated steam decomposes calcium fluoride.

PART II.—ECONOMIC.

Ornamental Fluorspar.—While the economic use of fluorspar on anything approaching a large scale is of very recent origin, this spar seems early to have attracted attention as an ornamental mineral. Pliny, in recording the working of lead at the surface in Roman Britain, was probably referring to Derbyshire.* And the finding in that county and in Yorkshire of Roman pigs of lead, one of which, according to its inscription, dates from A.D. 81,† while another goes back at least to the time of the Emperor Claudius‡ (A.D. 42-55), harmonizes with the tradition that the Romans worked the still older Odin lead-mine near Castleton, where "Blue John" occurs almost exclusively. Hence the reputed discovery of "Blue John" vases at Pompeii lends colour to the inference that the Romans were familiar with so striking a mineral.

Ornaments of fluorspar have been recorded from prehistoric mounds of the North American Indians.§

But it appears that from the time of the Romans all knowledge of fluorspar as a mineral of artistic value was lost in England, until its re-discovery in 1770 and the revival of the manufacture of ornaments from it.‖ We find a statement that for a "Blue John" vase made in 1815, 2 feet in height and 14½ inches in diameter, an offer of 200 guineas was refused in 1841.¶ The Museum of Practical Geology, London, has a larger specimen, standing 2 feet 8 inches high; but neither vase was made in one [redacted]

the mineral,* previously saturated with melted resin to minimize the risk of fracture. The same method is in use at the present day, for "Blue John" is still wrought at Castleton, Buxton, Matlock, and Derby, although the exhaustion of the old mine and the expensiveness of the material have strictly limited both the production and the sale of these ornaments.

The "Blue John" used for the manufacture of vases usually shows concentric banding in different colours and shades, various tints of purple and violet predominating, with purplish-brown and colourless layers. Very gradual heating almost to a white heat brightens the colour and produces the fine violet shade characteristic of the best specimens. But the process requires great care, in order to avoid decrepitation.† A similar intensification of colour takes place in nature to some extent, by exposure to the sun's rays.

Fluorspar was also used, with other spars and marbles, in mosaic work, an art much in vogue in Derbyshire in the middle of the nineteenth century,‡ but now little practised.

Commercial Fluorspar: Historical.—While the most important property of fluorspar from a commercial point of view, its action as a flux in smelting metals (whence the name fluor), has been known in all probability for many centuries, we first find a reference to its economic utilization in the *Philosophical Transactions of the Royal Society* early in the eighteenth century, where it is stated that "spar" was added as a flux to lead-ore in smelting operations in Derbyshire.§ J. Pilkington noted the same practice.‖ That fluor was the spar indicated, appears from a notice by Bishop Watson of "cubical spar" as the fluxing material for lead-smelting in Derbyshire.¶ Fluorspar was also used at the end of the eighteenth century in copper-smelting at

* *The Mineralogy of Derbyshire*, by John Mawe, 1802, page 79.

† *The Gem of the Peak: or Matlock Bath and its Vicinity*, by W. Adam, fourth edition, 1845, page 403.

‡ *Op. cit.*, page 409.

§ *Philosophical Transactions of the Royal Society* (from the Year 1719 to the Year 1733): Abridged and Disposed under General Heads by John Eames and John Martyn, 1734, vol. vi., part ii., page 193, quoted in "Geology of the Carboniferous Limestone, Yoredale Rocks, and Millstone of North Derbyshire," *Memoirs of the Geological Survey of England and Wales*, second edition, 1887, page 121.

‖ *A View of the Present State of Derbyshire*, by J. Pilkington, 1789, vol. i., page 121.

¶ *Chemical Essays*, by Bishop Watson, seventh edition, 1800, vol. iii., page 216.

Ecton, for Farey remarks that large quantities of it were obtained from the High Loft or Knowles Mine at Matlock in 1800, and taken to Ecton for that purpose.* The same author mentions that in that year (1800) fluorspar from Crich was freely used in the Butterley and Somercotes furnaces.† Here we have probably the first recorded instance of its utilization in fluxing iron or steel, its principal use to-day. That in 1800 fluorspar had not long been employed as a flux for iron-ore appears from Pilkington's statement in 1789, that "limestone is the constant and universal flux for iron-smelting."‡

Growth of the Fluorspar Industry.—In the United States, though the existence of fluorspar as one of the principle gangue-minerals of the lead-veins in Southern Illinois and Western Kentucky had been known long previously, it was in 1870 that fluorspar first began to attain some commercial importance.§ It is interesting to find that it was first raised regularly in England at the same time, or a little later. For the Home Office report gives no returns for 1873, but from 1874 onwards a small and varying yearly output is recorded, which began to increase rapidly from 1899. The following statistics, showing this rapid rise in the output of fluorspar, and the gradual fall and partial recovery in that of lead, are based on the Home Office returns for the United Kingdom:—‖

	Fluorspar. Tons.		Lead-ore. Tons.
1874-82 (9 years), average...	465	1873-82 (10 years), average	73,357

[redacted]

We find a close parallel in the history of fluor-mining in the United States. Mr. E. O. Ulrich, writing in 1905, states that, subsequently to 1873:—

> "Lack of transportation facilities, which had resulted in the abandonment of lead-mining as unprofitable on the lowering of the market-value of that mineral, soon caused the interest in the working of the fluorspar-deposits also to abate, and it is only within the last five or six years that activity has been renewed. The years 1900, 1901, and 1902 saw the organization of the majority of the companies now working in the district." *

Similarly in Derbyshire, the decay of the lead-mining industry, owing to the fall in the price of lead, not to exhaustion of the mines, probably retarded the development of fluorspar-mining; since, for 25 years subsequently to 1874, while the output of lead was steadily diminishing, that of fluorspar remained stationary or even declined. But from 1899, in England as in the basin of the Mississipi, an increasing appreciation of the economic properties of fluorspar began to prevail against the general stagnation of mining in the lead-districts. In Derbyshire it preceded by a few years a slight revival in the lead-industry, while it has given precedence to fluorspar as the most important mineral-product in the mining-field of Southern Illinois and Western Kentucky. Moreover, in Derbyshire the decided, though fluctuating, improvement in the prospects of lead-mining has further stimulated the fluorspar-industry, for both minerals can be worked together, where they are associated.

Production in Different Districts.—Although a very small quantity of fluorspar (not included in the Home Office returns) is raised in Cornwall, the two mining districts of Derbyshire and Durham monopolize between them practically the whole output of this mineral in the United Kingdom, as shown by the following figures:—†

OUTPUT OF FLUORSPAR FOR 1906.

	Tons.	Value. £
Derbyshire	27,684	13,579
Durham	14,165	6,444
Total	41,849	20,023

* The Lead, Zinc, and Fluorspar Deposits of Western Kentucky," by Messrs. E. O. Ulrich and W. S. Tangier Smith, *United States Geological Survey, Professional Paper No. 36*, 1905, page 20.

† *Mines and Quarries, General Report and Statistics*, 1906 [C.D. 3774], pages 190-191.

With the foregoing statistics we may compare the returns of output in the United States.*

OUTPUT OF FLUORSPAR IN THE UNITED STATES.

Year	Short Tons	Value. £	Value. Dollars.
1903 ...	42,523 ...	42,724 ...	223,617
1904	36,452 ...	46,951 ...	234,755
1905	57,385 ...	72,498 ...	362,488
1906	40,796 ...	48,805 ...	244,025

The difference of value indicated by these statistics is exaggerated by the high cost of transport in the United States. The production of fluorspar in that country is almost confined to Illinois and Kentucky, a very small proportion coming from Arizona, Tennessee, and Colorado.

Available Supply in Derbyshire.—While it is, of course, difficult to form even an approximate estimate of the amount of fluorspar in the Derbyshire limestone, a rough calculation of the cubic contents of known veins, in comparison with the amount worked yearly, shows that the available supply may be regarded as almost intact, and that it is capable of bearing the strain of a greatly increased annual output for a great number of years.

Richness of Veins.—In many of the veins the gangue consists almost entirely of fluorspar. Roughly speaking, where the proportion of fluor in the gangue is less than half, the vein would not be worth working for fluorspar unless exceptionally large.

[redacted]

contain as much as 99½ per cent. of calcium-fluoride: and, owing to the practically complete absence of quartz from the veins, Derbyshire "lump-spar" should be particularly suitable for processes in which silica is detrimental. The market-price of "lump-spar" is about 14s. per ton at the mines. "Gravel-spar" contains usually from 60 to 80 per cent. of calcium-fluoride, with perhaps some silica as an accidental impurity owing to the possibility of chert-fragments from the chert-bearing limestone of the country rock becoming mixed with it. Its price is about half of that of "lump-spar."

Method of Mining.—In a country like Derbyshire, where lead has been mined for many centuries, both by open-cast workings and by shafts, while the associated fluorspar has until recently been regarded as an almost worthless bye-product, the old mines naturally contain a great quantity of that mineral stored below in the "gob" and ready to hand. In addition to this store, since the revival in the lead-trade set in, fluorspar is being mined concurrently with lead, in those parts of the lead-district in which it occurs. The methods of lead-mining in Derbyshire have been more or less fully described by several authors, of whom Farey has given the most complete account of the processes. To these descriptions the reader is referred.*

Depth of Mining.—Though many of the old lead-shafts worked lead to a considerable depth, and exceptionally to about 1,000 feet at the Old End Mine at Crich, while the Ecton copper-mine was working to a depth of 1,320 feet at the beginning of the nineteenth century,† the limitation of fluorspar in vertical range to the highest part of the limestone, in conjunction with the usually gentle dip of the strata on the east side of the limestone-district, obviates the necessity of mining for that mineral to so great a depth, unless eventually it be followed far beneath the overlying shale.

* *A View of the Present State of Derbyshire*, by J. Pilkington, 1789, vol. i., pages 95 *et seq.*; *A General View of the Agriculture and Minerals of Derbyshire; drawn up for the Consideration of the Board of Agriculture*, by J. Farey, 1811, vol. i., pages 366 *et seq.*; "Lead and Lead-mining in Derbyshire," by Mr. A. H. Stokes, *Transactions of the Chesterfield and Derbyshire Institute of Mining, Civil and Mechanical Engineers*, 1880, vol. viii., page 67; Dr. A. Strahan in "Geology of the Carboniferous Limestone, Yoredale Rocks, and Millstone Grit of North Derbyshire," *Memoirs of the Geological Survey of England and Wales*, second edition, 1887, pages 118 *et seq.*

† *The Mineralogy of Derbyshire*, by John Mawe, 1802, page 111.

Commercial Uses of Fluorspar.—By far the most important commercial use of fluorspar is as a flux in the manufacture of steel and pig-iron. But the number of purposes to which it is applied is rapidly increasing. So far as the authors have ascertained, these are as follows:—(1) For fluxing in the manufacture of steel and pig-iron; (2) for fluxing in brass-founding;* (3) for fluxing in smelting lead,† tin, copper,† and nickel;‡ (4) as a flux for gold-ores;§ (5) in the reduction of aluminium from bauxite;§ (6) in refining lead and copper;* (7) in enamelling;‡ (8) in the manufacture of opalescent glass;‡ (9) in the manufacture of hydrofluoric acid and other chemical compounds of fluorine;‡ (10) in the manufacture of Portland cement;§ (11) for carbon-electrodes;§ (12) as a bonding for constituents of emery-wheels§ and (13) for optical purposes, chiefly in the manufacture of microscope-lenses.‖

Of fluorspar as a flux Percy states that, according to Berthier,¶ it acts in two ways, (1) by combining directly with silicates and forming fusible compounds; but chiefly (2) by acting upon silicates and causing an evolution of fluoride of silicon: that fluorine and silicon are thus removed, and the lime is relatively increased: that the agency of gases containing hydrogen seems not to be necessary to determine the reaction, for the calcium may be oxidized at the expense of the oxygen of the silica, and the silicon, reduced, escape in combination with fluorine.**

[redacted]

Of the application of fluorspar to the smelting of steel and pig-iron, Mr. J. Hyde Pratt states that spar containing as much as 4 per cent. of silica is used in the manufacture of steel on account of the great fluidity which it gives to the slag in open-hearth work, and that the lowest grade of fluorspar, both that which contains over 4 per cent. of silica and that which is mixed with calcite, is used in foundry-work:

"For this purpose the fluorspar gives a much cleaner iron, and its demand should be almost unlimited as foundrymen become better acquainted with its value for use in their furnaces."*

According to a further statement by Mr. Burchard, with regard to its use in iron- and brass-foundries, it makes the metal more fluid, permits the use of greater quantities of lower grades and scrap, and carries phosphorus, sulphur, and other impurities into the slag.†

In smelting lead, copper, tin, and nickel, it is said to be advantageous, though but little used for these purposes. Mention has already been made of its former use in England for the first two of these processes. It is stated to have an injurious effect on zinc.‡ In gold-smelting it has been found to assist in decreasing the loss of that metal.§

For the glass, enamelling, and chemical industries spar of a high degree of purity is required with less than 1 per cent. of silica.‖

Fluorspar is said to increase the lighting efficiency of carbon-electrodes and to diminish the amount of current required.¶

A small demand has arisen for fluorspar-crystals for microscope-lenses and other optical purposes, but there seems to be some difficulty in obtaining sufficiently large and clear crystals.

In conclusion, the authors wish to express their thanks to Dr. W. Pollard and Messrs. E. E. L. Dixon, H. H. Thomas, and O. T. Jones of the Geological Survey, for several valuable sug-

* Mr. J. Hyde Pratt in "Mineral Resources of the United States," *United States Geological Survey*, 1904, page 1032.

† Mr. E. F. Burchard in "Mineral Resources of the United States," *United States Geological Survey*, 1906, page 1064.

‡ *Loc. cit.*

§ "Fluorspar," by Mr. F. J. Fohs, *Engineering and Mining Journal* [New York], 1906, vol. lxxxi., page 46.

‖ Mr. E. F. Burchard in "Mineral Resources of the United States," *United States Geological Survey*, 1906, page 1064.

¶ F. J. Fohs, *loc. supra cit.*

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1899.—H. H. Arnold-Bemrose, "A Sketch of the Geology of the Lower Carboniferous Rocks of Derbyshire," *Proceedings of the Geologists' Association*, London, vol. xvi., page 165.

1905.—H. H. Arnold-Bemrose in *The Victoria History of the County of Derby*, vol. i. (Geology: fluorspar, page 12), London.

1905.—F. W. Rudler, "A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection," *Memoirs of the Geological Survey of England and Wales* (Derbyshire, pages 131 *et seq.*).

1907.—C. B. Wedd in "Summary of Progress for 1906." *Memoirs of the Geological Survey of Great Britain*, pages 7 *et seq.*

1907.—C. H. Vellacott in *The Victoria History of the County of Derby*, vol. ii. (Industries: fluor and calc spar, page 364), London.

1908.—W. M. Egglestone, "The Occurrence and Commercial Uses of Fluorspar," *Transactions of The Institution of Mining Engineers*, vol. xxxv., page 236.

The PRESIDENT (Mr. C. E. Rhodes) moved a cordial vote of thanks to the authors for their interesting paper.

The resolution was seconded by Mr. D. A. LOUIS, and carried unanimously.

Mr. C. B. WEDD briefly acknowledged the vote.

THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON, JUNE 5TH, 1908.

MR. CHARLES EDWARD RHODES, PRESIDENT, IN THE CHAIR.

[redacted]

THE UTILIZATION OF SEWAGE FOR THE PRODUCTION OF CRUDE OIL AND AMMONIA.

By MARMADUKE F. PURCELL.

The trouble that lies before every engineer dealing with sewage-works is how, when he has collected his sewage, he is going to deal with the solids which it contains. This is not a weighty problem in the case of small seaside-towns, but it becomes more complex as the size of the town or city increases; for, where large bodies of dejecta are sent away on the tide, there is ever the danger, and (in some cases) the certainty, of such deposits returning with the tide and being deposited on the foreshore, to become a standing danger, an intolerable nuisance, and a waste of material of vast value. This is bad enough at the sea-coast; but the problem becomes more acute the further we go inland; for then we must either pollute our rivers (still losing material of value), or we must treat the solids as manure, selling the sludge or cake to the farmers, or use it on sewage-farms. Each case has its merits, but also its great demerits. In the case of the farmer, the value largely depends upon the precipitant used in the settling-tanks, which may or may not be suitable for the prevailing crops in the district; but, even in the event of the deposit being suitable, the farmer objects to employ his horses, carts, and men in drawing a load which contains more water than manure; another point is that, owing to the sludge having the precipitating material mixed through it, its full decomposition is delayed after being dressed over the land, consequently delaying the benefit to be derived. As a resultant, the farmer turns to artificial or natural manures, the action of which he knows and the results of which he can predicate.

With regard to sewage-farms, this question is a delicate one, and one which the author would prefer to leave in abler hands than his; but he is given to understand that for the perfection

of the system the area must be very considerable, as the sludge requires to be dug in, and the ground left fallow for three years, so as to obtain the best results from the material; so that in a scientifically-planned and correctly-administered sewage-farm it is only possible to have one-third of it under cultivation at any one time. This is one aspect of the sewage-farm, but there is another and more important one, namely, the indestructibility of disease germs by the ordinary precipitants used at the depositing-tanks, and hence, when the sludge is spread on the farms, the consequent absorption of such germs from the soil and their incorporation into the cellular tissues of the vegetables grown upon these farms, their subsequent transference upon use to the human system, and the consequent spread of such diseases as typhoid, etc.

This point alone should lead us to endeavour to find some other method of dealing with and turning to benefit this valuable product which every community produces, most throw away, some misapply, and all would like to utilize; but the question arises: how is this to be done on a commercial scale, combining efficiency and economy? how to eliminate the dangerous factor and produce a source of revenue out of what is at present a menace and a loss?

These were the questions put before the author some years ago by a very distinguished member of The Institution of Mining Engineers, who himself was a pioneer in the same field. The

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object of the production of dilute ammonia (as ammonia-water), and a residue which can be utilized for converting into cement, for which purpose it is excellently fitted, especially where lime has been the precipitant used in the separation of the solids and the affluent.

London sludge so treated contained:—

	Per Cent.	
Moisture	58·06	Nitrogen, calculated as ammonium-sulphate, 0·87 per cent., wet cake.
Organic matter ...	16·69	
Mineral matter ...	25·25	
Total ...	100·00	

The mineral matter contained:—

	Per Cent.		Per Cent.
Carbonate of lime	7·94	Oxide of iron	0·97
Free lime	2·45	Alumina	3·39
Silica	8·08	Phosphoric acid	0·65

On examination of these results, it is evident that, if we dry the sludge, we have a material capable of yielding by distillation very large amounts of ammonia, and also an oil, valuable as a carburetting material for enriching gas.

The first experiments were made on a very small scale in the laboratory with pressed sludge from London, the results being most encouraging. The next experiment was tried in a gas-retort, with poor results as to the yield of oil and ammonia; but it clearly demonstrated that the vertical position of the retort was the correct one if the most abundant results were to be obtained, and, again, that the cake must be distilled in a retort which could give two or more different temperatures—one (the lower) at which the elements present in the cake chemically combined to form the oil-vapour, and another at which the nitrogen (still present as such in the spent material) was burned, so to speak, in an atmosphere of steam, and converted into ammonia by the action of the caustic lime produced in the operation. The next step was the erection of a small experimental plant, fired by gas. The apparatus was small and imperfect, but considerable experience was gained by its use, and oil and ammonium-sulphate were obtained. It also demonstrated that external heating of the retort was valueless if a high percentage of ammonia was to be produced; consequently a retort on the principle of a shale-retort would be more efficacious. The

oil obtained would be excellent for liquid fuel or for gasefying. The residue from the retort was a valuable material for conversion into cement. A considerable body of incondensable gas is produced during the distillation, which could be used, either as fuel to dry the pressed cake, or be turned into the retort-benches; indeed, the process which would be adopted would be similar to the process of distillation used in Scottish shale-works, with this difference—that the sewage to be distilled must be dried, and this could be effected by the waste gases produced during distillation and by carrying the hot-gas flues under specially arranged floors designed to carry the pressed sewage-cakes. With these modifications, the process would correspond identically with the shale-distillation: oil, gas, and ammonia-water being produced and condensed in suitable receivers, and afterwards separated, and the ammonia obtained in the form of sulphate. In shale-oil works the principle factor is the quantity of ammonium-sulphate obtained per ton of shale distilled. This in Scotland may be taken as running between 25 and 37 pounds per ton (the highest average).

Appended is a copy of the balance-sheet of an oil-works using a Henderson retort, and from it the following figures have been obtained:—

(1) The yield of crude oil per ton of shale is about 37 gallons.
(2) The yield of ammonium-sulphate is about 18 pounds.
(3) The cost of winning and obtaining the shale is 4s.

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The following table contains some of the results:—

Wet Cake from	Ammonium-sulphate. Pounds per Ton.	Residue. Per Cent.	Oil per Ton. Gallons.	Water per Ton. Gallons.
Cross Ness	57·56	39·00	7 to 11	54·10
Leyton	58·80	68·40	9 to 10	52·00
Wimbledon	65·63	56·00	5	51·00

In dealing with the cake, it is necessary that it should be nearly dry (not containing more than 15 per cent. of moisture) before distillation in the retort, and to dry it to that consistency, the waste heat of the retorts could be utilized, and also the gases given off during distillation. Even should it be necessary to get auxiliary heat to effect the drying, the cost of such heat would not equal or approximate to the cost of mining the shale, that is, 4s. per ton; consequently, if we obtain products from the sewage which are as valuable as those obtained per ton of shale, the process stands upon a good remunerative basis. Certainly the oil is neither so good in quality nor so large in quantity as that obtained from the shale, and would probably prove of about the value of 1½d. per gallon for gas enrichment; but, on the other hand, the ammonia-yield would be nearly double that from shale, whilst, as before mentioned, the residue, when ground, etc., would make a valuable cement-material.

The yield of one ton of pressed sewage-cake containing 15 per cent. of water would be roughly as follows (and the writer may say at once that 10s. for the residue is not a fraction of its value):—

		s.	d.
20 gallons of crude oil at 1½d. per gallon		2	6
80 pounds of ammonium-sulphate at 1½d. per pound		10	0
6 hundredweights of residue suitable for cement		10	0
Total yield from 1 ton of pressed sewage-cake ...	£1	2	6

The cost of obtaining this would be approximately as follows:—

	s.	d.
Drying 2 tons of sewage-cake, say 2s. per ton for coal used in addition to the waste-heat from the retorts	4	0
Cost of distilling and producing the crude oil and ammonia ...	4	6
Cost of crystallizing the sulphate of ammonia and the cost of sulphuric acid necessary	2	6
Total cost of treating 1 ton of pressed sewage-cake	11	0

In the foregoing, the amount of ammonia is taken at much less than what is really obtained by the process, and the value of the residue is taken very low indeed.

Subsequently a consignment of pressed cake was sent to a shale-oil works for distillation; and there they very courteously carried out the distillation in their experimental retort, with the following results:—

	Per cent.
Moisture	71·335
Organic matter	10·210
Ash	18·455
Total	100·000

On distillation in the experimental retort, in the presence of steam, the following results were obtained:—

	Original Sample.	Dried Sample.
Oil, pounds per ton	11·779	41·094
Ammonium-sulphate (free), pounds per ton	19·884	69·367
Total, pounds per ton	24·486	85·421

In this case, the figures are those certified to by the head of the shale-works, and are not the author's. These works make the larger portion of their profits out of the ammonium-sulphate produced; and in their experiments in an unsuitable retort built for the distillation of shale, they got some 50 pounds of ammonium-sulphate per ton more out of the sewage-contents than out of shale. This does not take into account the gases evolved, nor the oil, nor yet the residue of combustion which

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APPENDIX.—Cost of Distilling 1 Ton of Shale, and Value of the Products derived therefrom.

Dr.	£	s.	d.	Cr.	£	s.	d.
To total cost of getting 69,808 tons of shale, equal to about 4s. per ton	13,994	0	0	By price of 2,555,680 gallons of oil produced from 69,808 tons of shale (or 36·60 gallons per ton)	28,843	0	0
,, sulphuric acid required, equal to 6·5d. per ton	1,945	0	0	,, price of 11,179 hundredweights of ammonium-sulphate, at 13s. 11d. per hundredweight ...	7,801	0	0
,, coal, equal to 1s. 3d. per ton	4,403	0	0	,, price of 80,661 gallons of naphtha	458	0	0
,, general repairs, equal to 4·6d. per ton ...	1,394	0	0				
,, wages, equal to 1s. 8d. per ton	5,906	0	0		£37,101	0	0
,, expenditure on horse labour, etc., expenses, commissions to managers and clerks, salaries, etc., taxes, and surface damages, equal to 4·5d. per ton	1,242	0	0				
Total cost, 8s. 2½d. per ton ...	£28,884	0	0				

The profit derived under each head may be held to be as follows:—

	Prices Received.	Cost.	Profit.
Oil	£28,843	£25,268	£3,575
Ammonium-sulphate	7,801	3,188	4,613
Naphtha	458	311	147

The few words that he has had the honour of presenting to the members are only put forward as the result of experiments carried out with an encouraging amount of success, and now offered with the intention of eliciting the opinions of those more able than the author; and to point out this most valuable source of matter for utilization, which now constitutes a danger and a nuisance, or is ruthlessly thrown away.

The PRESIDENT (Mr. C. E. Rhodes), in moving a vote of thanks to Mr. Purcell for his paper, said that at the present time he had in view the utilization of a bye-product plant in order to deal with the sewage of a very important town where the sewage-works were near their coking plant. Any hint which would enable one to adopt a scheme that might turn out advantageously both for the colliery proprietors and for the local authorities was undoubtedly of advantage, and he therefore welcomed Mr. Purcell's paper on that account.

The vote of thanks was cordially adopted.

THE OIL PROSPECTS OF CENTRAL BRITISH SOUTH AFRICA.

By Dr. C. G. S. SANDBERG.

I.—Introduction.

The oil prospects of Central British South Africa, that is, the Karroo-covered area of Cape Colony, the Orange River Colony, the South-eastern Transvaal, and North-western Natal, have been the subject of much controversy, and for some time attracted a little attention.

Some prospecting, in a primitive, unsystematic, and entirely inadequate way, went on here and there. Wells were sunk and bore-holes drilled near places where oil-indications were found. The choice of the sites of such bore-holes and wells was, however, never decided upon as a result of a careful study of the region by competent experts, and seldom were the bore-holes started with such diameter, nor continued with those precautions, proved to be essentially necessary in all the well-known oil-fields of the world.

At a very shallow depth these holes were discontinued, and no "spouter" having been struck in an uncased 1½ to 3 inches hole of exceptionally 1,000 to 1,500 feet depth, or in a larger sized of some 300 or 400 feet, a new "convincing proof" (acquired at the cost of a thousand pounds or more) was added to the several of similar nature already existing, of the unproductiveness of the South African fields.

The squandering of much money in this way without success, naturally secured the future prospects of these fields a reputation similar to the one enjoyed by the Rumanian fields previous to the appointment of the Rumanian Royal Commission about four years ago.

The conclusions arrived at and the subsequent results obtained by this geological and technical commission again conclusively demonstrated the fact, already verified in other parts of the world at the cost of tremendous unprofitably-spent capital, that

prospecting for oil cannot be done in a loose and haphazard way, and that to secure any possible chance of success, research-work for this mineral must be done under the supervision of thoroughly competent specialists, who shall only point out the spots where bore-holes must be drilled after having acquired, by a minute and careful study of the region, a thorough knowledge of its tectonic structure.

Any other course adopted in the prospecting for oil is doomed to failure before its inception, and had better not be started at all.

II.—Oil-deposits in General.

The origin of the huge deposits of gaseous, liquid and more or less solid bitumen is attributed, as is well known, to :[*] (*a*) inorganic " ur "-material; (*b*) organic " ur "-material.[†]

(*a*) According to the inorganic genetic theory, petroleum is to be regarded as the condensation-product of hydrocarbons, formed by the contact of water with metallic carbides in the molten liquid or viscous interior of the earth.

Although the inorganic-origin theory to-day perhaps only counts comparatively few supporters, they yet can boast of world-famed names amongst their ranks, as also that their opponents have never yet been able to explain satisfactorily both the evident relation of vulcanism and petroleum, and much less the enormous quantities of the mineral accumulated in comparatively small areas.

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The *milieu* in which the original deposition took place most probably was: (*a*) along the coast in lagoons, marshes, estuaries, and the mouths of big rivers; (*b*) in desert regions; and (*c*) in regions propitious for the accumulation and bituminization of large quantities of vegetable and animal matter in stagnant, salt and fresh waters.

Active sedimentation is in all cases necessary for covering up quickly the organic remains and thus preventing oxidation.

All petroleum geologists, however different their views as to the genesis of the mineral may be, are unanimous in acknowledging that the presence of workable oil-deposits is intimately and inseparably connected with the tectonic structure of each particular region, and that they are situated in one or more zones, in the main parallel to the direction of the principal folding of the sedimentary strata of the area.

III.—The Karroo Formation of Central British South Africa.

The Karroo system is sub-divided as follows:—*

Karroo System.	Upper Karroo or Stormberg Series.	Volcanic beds. Cave Sandstones. Red beds. Molteno Beds.	
	Middle Karroo or Beaufort Series.	Zone of the specialized Theriodonts. Sandstone and shales with *Dicynodon*. Sandstones and shales with *Pareiasaurus*.	
	Lower Karroo or Ecca Series.	Upper sandstones and shales Dwyka Conglomerate Lower sandstone and shales.	zone of the *Mesasaurus*.

A.—*Lithological*.—The oil indications of Central British South Africa nearly all occur in the region covered by the strata of the Karroo Series, which are of Carboniferous, Permian, and, in their upper levels, of Triassic age.

Lithologically, these series consist of an alternation of shales and sandstones, with occasional conglomerates in interminable succession, attaining a thickness which has been estimated by Mr. A. W. Rogers† at a maximum of 18,100 feet.

* For the geographical distribution of the system see the following:—"Géologie de la République Sud-Africaine," by Dr. G. A. F. Molengraaff, *Bulletin de la Société Géologique de France*, 1901, fourth series, vol. i.; *The Geology of South Africa*, by Dr. F. H. Hatch and Dr. G. S. Corstorphine, 1905; *Geology of the Cape Colony*, by Mr. A. W. Rogers, 1905.

† *Loc. cit.*

This complex has been subjected to mountain-folding pressure, and traversed by igneous intrusions of later (younger) date in the form of pipes, dykes, interbedded sheets, and flows, occurring in distinct relation to the tectonic structure of the region.

B.—*Palæontological.*—The Karroo formation of the whole of South Africa is extremely rich in fossil remains, both of the fauna and of the flora of the period. Animal and plant life must have been extremely exuberant, as is evidenced by the numerous remains found in these strata of large amphibia, reptiles, fishes, bivalves, and plants.

Extensive coal-beds are found in Central, Eastern, and Southern Transvaal, in North-western Natal, in the Northern and North-western parts of the Orange River Colony, and in the Northern part of the Cape Colony. Some of the Karroo shales in the Kimberley district proved so highly impregnated with vegetable remains that they have been burning for several years, after having been spontaneously ignited. In the central part of the Orange River Colony silicified wood is abundant, and recently Messrs. Mellor and Leslie* have described the remains of a petrified forest which they discovered in the bottom of the bed of the Vaal river, near Vereeniging.

Magnificently preserved casts of fishes are numerous in certain shales of the Karroo formation in the Vrede, Harrismith, Bethlehem, Ladybrand, and Fiksburg districts (Orange River Colony), and remains of the huge reptilian and amphibian fauna are notori-

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IV.—Critical Discussion of Karroo Oil Prospects.

The questions next to be investigated are: Were the conditions prevalent during the Carboniferous and subsequent geological periods favourable or unfavourable to the possible formation and subsequent accumulation and storage of oil-deposits? The objections raised against the possibility of extensive oil-deposits being present in these strata are: (1) The absence of marine deposits. (2) That the strata of the Karroo Series are and always have been devoid of the fundamental material necessary for the formation of oil-deposits, which, according to some authorities, consists of marine animal organisms, according to others both of marine, vegetable and animal remains. (3) That the strata of the Karroo formation, with the exception of its southern and south-western border, do not show any evidence of folding. They are, it is argued, lying practically horizontal, and do not show the gently-curved anticlines (and synclines) necessary for the storage of large quantities of oil. (4) That all the oil-indications in the Karroo-covered area are directly or indirectly connected with igneous dykes, interbedded sheets, etc., and that the oil now found in the cracks and fissures of these igneous rocks is simply a product of the dry distillation of coal-beds and bituminous shales traversed, in their upward course, by these igneous rocks when still in a molten condition. (5) That these molten igneous masses have, by their passage through the sedimentary strata, evaporated any and all oil-deposits which may have existed in these strata previously. The remnants of these vapours were subsequently condensed in the cracks and fissures during the cooling of the igneous masses.

What, now, is the value of these objections, when weighed in the scale of our present knowledge of the genesis of oil-deposits, a knowledge which is acquired from practical experience, gained directly and indirectly during scores of years in the different oil-fields of the world, during their exploration and working?

As no marine animal or vegetable remains have yet been found in these strata, it may for the present be admitted that no marine deposits exist in this Karroo formation. The salt-and-gypsum deposits, in the western part of the Orange River Colony, and the frequent striking of brine in bore-holes sunk in the western and northern portions of that colony and adjoining Cape

Colony, might on closer investigation, however, perhaps point to desert or coastal conditions having prevailed in that part of the area during the deposition of these strata.

The admission for argument's sake of the total absence of marine deposits in the Karroo formation, does not seem to warrant the conclusion that petroleum could not have been formed in these strata, as it is also originated in a continental *milieu*, as for instance, desert regions, peat regions, etc. Fossil marine organisms consequently need not be necessarily represented in oil-producing strata.

It is further noteworthy that Stahl[*] now concurs with Dr. Potonié's views, namely, that salt is not absolutely necessary for the formaiion of petroleum, and that this mineral must be looked upon as a product of the dry distillation of the "sapropel-rock."

That petroleum is not exclusively zoogenic may now be considered as conclusively proved. It is sufficient, therefore, to remember that Reichenbach extracted paraffin from wood, and that petroleum, as is well known, can be extracted from turf. That Peckham, Orton, Phillips, and others, regard the petroleum of New York, Pennsylvania, Ohio, and West Virginia to be of vegetable origin is notorious,[†] and that Engler suggests this to be perhaps a possible explanation of the feeble optic activity of the Pennsylvanian oils[‡] is not unknown.

In Australia, Russia, and America, the kerosene-shales, containing also remains of fishes and reptiles, are essentially phyto-

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can be said of the principal oil-bearing strata of Galicia, and it is noteworthy that Prof. R. Zuber of Lemberg, the great Galician petroleum authority, regards petroleum to be essentially a product of vegetable remains.*

In South Africa the oil-shales essentially derive their bituminous contents from terrestrial flora. Apart from the eruptive intrusions occurring in the oil-shale regions of South Africa, the kerosene-shales of Australia occur tectonically in somewhat similar conditions to those observed in South Africa. The reason why, according to Dr. Potonié,† the Australian oil-shales did not release their oil-contents, and thus failed to produce workable free-flowing oil-deposits in adjacent porous rocks, is: that they are situated at too shallow a depth; that no considerable mountain-folding pressure ever was brought to bear on them; and that eruptive rocks in the region are only present in very subordinate quantities.‡ Volcanic action, after the deposition of the oil-shales, was certainly not lacking in the Orange River Colony or in the adjoining area of the Cape Colony, whilst folding was very energetic on the southern and south-western border of the Karroo-covered area, apparently diminishing in intensity towards the north and east.

And when we investigate the conditions prevailing in the extensive eastern and southern United States oil-fields we also find that the folding of the strata there has been but very gentle indeed. Thus the dip of the Bradford region (New York) is only about 70 feet per mile; that of the Southern and of the Butler Belt (Pennsylvania) rarely exceeds 34 feet per mile; the extensive fields of Indiana and Ohio have a dip of 1 to 10 feet per mile; whilst at Lima (Ohio) the dip is almost *nil*.§

In Galicia, at Boryslaw and Tastanorvicz, the productive wells are found in the region where the strata are almost horizontal. Excessive folding, as a rule, has been found detrimental to the storing of large quantities of oil in all the known oil-fields of the

* "Kritische Bemerkumgen über die Modernen Petroleum-Entstehungs-Hypothesen," by Dr. R. Zuber, *Zeitschrift für Praktische Geologie*, 1898, pages 84 to 94; and personal communications to the author.

† "Zur Frage nach den Urmaterialen der Petrolea," by Dr. H. Potonié, *Jahrbuch der Königlich-preussischen geologischen Landesanstalt*, 1904, vol. xxv., No. 2.

‡ Doelter textually says: "Das Bitumen von Schiefertonen wird durch Diabas ausgetrieben und in den weiteren Partien des Schiefers aufgenommen," *Petrogenesis*, by Dr. C. Doelter, 1906, page 152.

§ *Petroleum and its Products*, by Sir Boverton Redwood, 1906, page 110.

world, especially when subsequent erosion has been the means of removing the capping of the anticlinal ridge of the oil-bearing-fold, and transforming it into an open anticline.

That all the indications of oil in the Karroo are in direct or indirect connection with igneous rocks, is an assertion which is distinctly misleading and even false. It is true that the majority of prospects of free oil brought to the notice of geologists and the public are of such nature. But this is principally due to the fact that these rocks are not porous, that the oil consequently accumulates in very appreciable quantities in the cracks and fissures of these rocks, and thus more readily attracts the attention of prospectors and laymen than evenly impregnated sandstones and shales, which show little or no outward sign of their impregnation.

On closer study, however, it is found that sandstones and shales, away from any igneous intrusion, are also impregnated by the mineral. Such is known to be the case, for example, in the Harrismith district, in the Reitz district (ozokerite impregnating a sandstone), in the Bethlehem, Kroonstadt, and Bloemfontein districts, etc. Inflammable gas bubbles up from a spring at Dealesville (near Brandfort); an emanation of mud and sulphuretted hydrogen exists on Joubertkraal, near Bloemfontein; oil is continually being struck in shallow bore-holes (drilled in looking for water) in the above-mentioned districts, and often seen as a film over stagnant waters.

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The brown coal of the principal oil-horizons in Southern Sumatra has been changed into magnificent glanzkohlen in those igneously injected anticlines.* The supposition would, therefore, not seem to be very hazardous, that these very igneous intrusions may have been the means of freeing, through distillation, the oil from the brown-coal layers and the clay-shales to which it was originally bound, and making it accumulate in neighbouring porous sandstones, conglomerates, and shales.

A similar action of a dolerite-sheet on oil-shale is recorded from the Cape Colony, and will be described below.

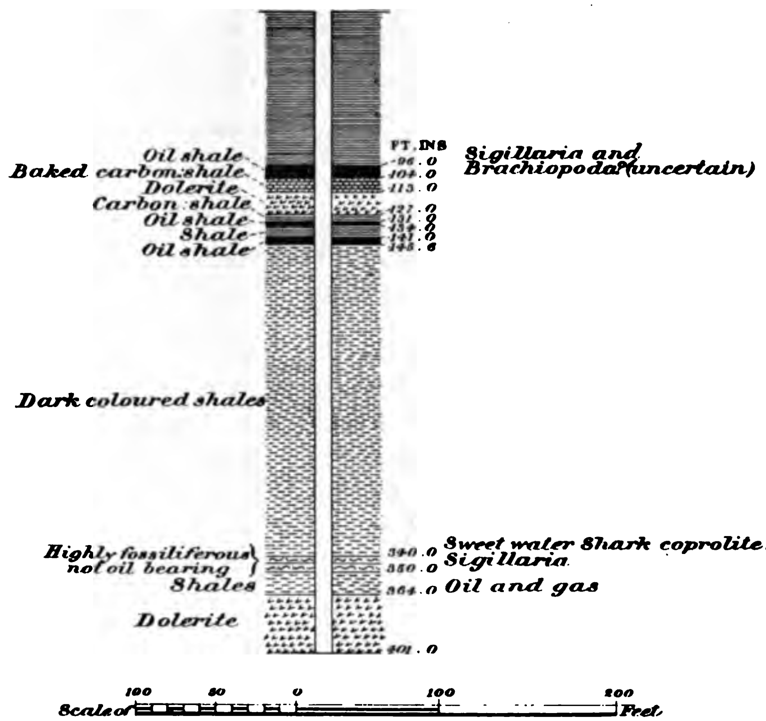

FIG. 1.—SECTION OF BORE-HOLE ON ELANDSDRAAI FARM, CAPE COLONY.

V.—THE OIL-SHALE OCCURRENCE ON THE ELANDSDRAAI FARM, CAPE COLONY.

The Elandsdraai farm is situated in the Hopetown district, and is being prospected by the Cardinal Oil Syndicate, under the

* Dr. H. Hirschi (late chief geologist of the Royal Dutch Petroleum Company, Sumatra), private communications, and "Topographische und Geologische Beschreibung der Petroleum Gebiete bei Moeara-Enim (Süd Sumatra)," by Dr. A. Tobler, *Tijdschrift van het Koninklijk Nederlandsch Aardrijkskundig Genootschap*, 1906, second series, vol. xxii.

able management of Mr. J. B. Parkinson; the data of the borehole section (fig. 1), which is typical for the region, have been kindly furnished to the writer by that gentleman.

When looking at the accompanying section, it will be noticed that the drill, from the surface downwards, first went through 96 feet of blue shale, with bands of lighter-coloured calcareous shale. From 96 to 104 feet the drill passed through a solid layer of soft black oil-shale, with a rather low percentage of oil and a comparatively high percentage of ammonia. This shale rests upon a layer, 9 feet thick, of a hard-baked shale considerably poorer, the bituminous contents of which have been "coked" more and more in direct relation to its proximity to the igneous sheet immediately supporting these shales.

From 113 down to 127 feet the drill traverses a dolerite sheet, showing oil in its cracks and crevices, no doubt from the condensation of the vapours generated by the distilling action of the dolerite on the underlying shales.

A hard-baked sterile layer of shales 4 feet thick separates this igneous intrusive mass from a second deposit of black oil-shale, 3 feet thick, very poor in oil-contents, and supported in its turn by 7 feet of ordinary dark-coloured shales, followed by a third layer of oil-shale, 4 feet 6 inches thick, also poor in oil-contents.

From here, 145 feet 6 inches down, until a depth of 340 feet has been reached, the drill goes through a homogeneous mass of dark shale to disclose a layer of shale, 10 feet thick, extremely [redacted]

That the oil-shales of the region must already have been existing as true oil-shales before the igneous intrusions. For the molten igneous mass of the upper dolerite sheet has evidently distilled part of the oil-shales' volatile contents, "coking" that portion of the shale nearest to its contact. The subsequent absorption, condensation, and accumulation of the oil thus distilled, by adjacent porous sedimentary rock has thus become possible, in the same manner as has most likely occurred in the highly volcanic oil-fields of the Malay Archipelago.

The lower thick dolerite sheet, although only separated by 14 feet of non-fossiliferous shales from the rich fossiliferous shale above it, left this last-named layer unchanged and devoid of oil. This fact furnishes additional, and it would seem conclusive, proof that the oil-shales above and below the much thinner uppermost dolerite sheet were already true oil-shales before the igneous intrusion took place, and that the oil-contents in these upper shales were not generated by the dry distillation of an igneous intrusion of a bituminous shale, but were a primary impregnation similar to that of other oil and kerosene-shales in other parts of the world. In other words, an oil-deposit already existed here which only wanted the action of a distilling agent (pressure, folding, or igneous intrusions) to liberate the viscous, liquid, and gaseous hydrocarbons from the rock in which they were too intimately fixed, for the possible impregnation of more porous strata and the consequent production of secondary oil-deposits.

But there is more to be learned from this interesting occurrence; oil and gas accumulated in the bore-hole near and at the contact of the non-fossiliferous sedimentary rock and the dolerite sheet; and oil was found in the small cracks and fissures of this igneous rock. We are, consequently, in the presence of a sedimentary rock showing distinct signs of such secondary impregnation, and as the magma did not distil the oil found in its own body from the fossiliferous sedimentary rock above, we must logically conclude that this lower dolerite sheet derives its oil-contents from some other oil-deposit (shale or other) lower down, in the proximity of which it passed, or which it traversed in its upward course. The oil-contents of this lower deposit have been more or less intensely distilled, that is, freed, and have been driven to a recipient rock elsewhere by the heat of the molten magma.

We thus have here the proof that migration of oil to adjacent deposits under the influence of heat from molten magma is, as already alluded to above, not only a hypothetical possibility, but has actually occurred.

The feeble inclination of the sedimentary strata, and the repeated alternation in them of porous and impermeable layers, exclude the probability of these distillation-products having reached the atmosphere and having been evaporated before their subsequent re-condensation in adjacent porous rocks.

VI.—The Bloemfontein Townlands Bore-holes.

The bore-holes sunk on the Bloemfontein Commonage show the following data:—

After going through the surface-soil and some coarse-grained soft sandstone, the drill was driven into shales in which water first and soon afterwards, between 60 and 90 feet, oil was struck, in three bore-holes of 1¾ inches diameter.

The quantity of oil when first struck was estimated by the acting Minister of Mines of the Orange River Colony at 1 quart to every 1,000 gallons pumped.* It is a very liquid yellow oil, which evidently has gone through a certain amount of natural filtration (similar to a kind of distillation) by the strata through which it passed. Here again, then, are we in presence of a free-flowing oil-deposit.

Near Beaufort West, Cape Colony, on the Kamfers Kraal [redacted]

districts (Temworth farm), the Bethlehem district (Golden Gates upper basaltic sheet), etc. But everywhere the impregnation of such dykes and flows is very limited in extent, varying from an area of a couple of square feet to 20 or 30 yards. Beyond these localities the dyke or sheet in question is found to be barren either over its whole further length of several miles or showing some very few more similarly impregnated spots at a considerable distance away from the first. This would seem to point to oil coming up along small fissures and cracks in the dolerite-dykes and through the sheets, from deposits situated lower down.

It would be going beyond the limits of this paper to describe other equally interesting occurrences. The foregoing were therefore selected as being most instructive and conclusive.

VII.—Conclusions.

Indications of the probable existence of oil-deposits are found over a large area of the Orange River Colony and the adjoining Karroo-covered area in the shape of oil impregnating sandstones, shales, sand and the cracks and fissures of igneous dykes; also in the shape of impregnations of ozokerite, lignite, etc., in sandstones, the oozing out of gas and oil, the existence of small mud volcanoes, etc. These indications appear at the surface, and are met with in depth whilst boring for water, rendering the water undrinkable on such occasions.

From a geological point of view, the strata of the Karroo Series do not exclude the possibility of large and workable oil-deposits being present therein. Lithologically, their constitution, being one of alternate layers of porous and impermeable layers, is extremely favourable to the possible storage of large quantities of oil. Tectonically, they compare favourably with other large oil-fields of the world, whilst palæontological evidence is abundant to show that the organic fundamental material for the production of oil was not lacking.

The indications found in several parts of this large area are so numerous and varied, and the existence of oil-deposits in the form at least of oil-shales before the periods of igneous intrusions in these strata is so evident, that the unbiassed mind must necessarily come to the conclusion, when weighing these considerations, that the possibility of finding workable oil-deposits in the Karroo-covered area is, to say the least, not excluded.

The writer, moreover, considers it extremely gratifying that Sir Boverton Redwood, who not so very long ago was very sceptical on the point, now concurs in this opinion on the strength of a considerable amount of evidence lately placed before him by others, accumulated entirely independently from the author of this paper.

In conclusion, the writer begs to thank all those who have directly or indirectly assisted him in accumulating data for this paper, and more especially Dr. Stollrieter of Bloemfontein, Mr. F. B. Patterson of Kimberley, Prof. Dr. Zuber of Lemberg, and Dr. H. Hirschi of Zurich.

Dr. G. A. F. Molengraaff (The Hague) wrote that he was, personally, not sanguine as to the prospects of a future oil-industry in South Africa. He must, however, admit that he was not well enough acquainted with some of the facts, which formed more or less the backbone of Dr. Sandberg's argument, to enable him to supply written remarks of any importance. He still adhered to the theory of the origin of rock-oil as a derivate from animal remains; but he must admit that objections had been brought forward against this theory, and not without success.

Dr. C. G. S. Sandberg (Arnhem, Holland), in reply, wrote that, whilst thanking Dr. Molengraaff for his criticism, the probability of the existence of large oil-deposits in the [redacted]

NOTES ON THE WINNING OF CRUDE OIL.

BY D. M. CHAMBERS.*

Historical.—Petroleum products are at the present day amongst the commonest commodities met with in the markets of the world. Nevertheless, the appearance of these products as general articles of commerce is of very recent date, and this, in spite of the fact that the existence of deposits of what we know now as crude oil has been known from earliest times. Herodotus, writing about 450 B.C., mentions the production of asphalt, salt, and oil at the pits of Kir-ab-ur-Susiana (Persia), and describes the methods employed in raising these minerals. Pliny, Plutarch, and others, also mention the discovery of what they generally term "oil," and it is highly probable that some of the references in the Old Testament to salt should, rightly interpreted, be understood as referring to petroleum. In like manner, the "slime pits of the Vale of Siddim" (Genesis, chap. xiv., verse 10) probably refer to petroleum deposits.

Coming to more recent times, we find Marco Polo writing at the end of the thirteenth century of oil-springs near the now famous Baku district, and the city of Baku itself was the principal city of the sect of Fire Worshippers some centuries earlier. Early in the seventeenth century, the oil-deposits of America began to receive general notice, though evidence is to hand that the Indians of that continent knew of and used the oil obtained from these sources for centuries. In the eighteenth century, oil-deposits in various parts of the world received more and more attention as the use of the mineral itself in the arts increased, and thus gradually the petroleum industry of the present day came into being. As to the purposes to which the crude oil was put in these early times, we read that the ancient Egyptians used it for embalming purposes, whilst its use was general as a fuel for religious and other rites, and for medicinal purposes. In comparatively recent times, the lubricating properties of the crude oil seem to have become apparent. It would

also seem that vanity as a male characteristic is not a result of modern degeneracy, since it is recorded that the Galician peasants made use of the crude oil found in their country as a hair-oil in the eighteenth century.

Naturally, in those early days, no systematic mining of the crude oil took place. The oil was generally found to accumulate on the surface of streams and lakes, and was collected by skimming. Sometimes shallow holes were dug, into which the crude oil gradually percolated. For a long time the crude oil was used in the form in which it was won; later it was subjected to a straining process. Refining, as understood at the present day, is of very recent discovery, and this perhaps explains why petroleum, although known of from almost pre-historic times, has only lately become of universal use.

Modern Development.—Though crude oil is found at the present day in various quarters of the world, nevertheless practically over 90 per cent. of the whole world's supply is obtained from the oil-fields of the United States of America and Russia. After these, the chief producing countries are Rumania, Galicia, Borneo, Germany, Canada, and, in much smaller proportion, Japan, China, the West Indies, Egypt, South Africa, France, Switzerland, Greece, and Britain. It is thus apparent that for all practical purposes the petroleum industry of the world is the petroleum industry of the United States of America and Russia. In America, a well, drilled for brine, was the precursor of all [redacted]

serviceable illuminant could be obtained in this way more cheaply than by Young's process. The first well actually drilled for petroleum alone was put down by Drake at Titusville Oil Creek, in 1859, and the success attending Drake's operations led to a veritable oil fever, with the result that the present oil-industry of America was created.

In Russia, the industry as known at the present day may be said to start from the year 1872, when a monopoly which had been granted to a merchant named Meerzoeff was abolished. At this date many dug shafts existed, and the quantity of crude oil won was over 6,000 tons in that year. Five years later, many drilled wells existed, several refineries had been erected, and the production increased at a tremendous pace as a result of the enormously rich gushers which were brought in. Russia has been essentially the home of big fountains; for instance, a well struck in 1875 yielded as much as 600,000 gallons per day, and had a disastrous effect on the price of the produce of the fields generally.

As regards the other sources of supply at the present day, their activity dates from much later years. In Galicia, the first properly drilled well was sunk in 1893, and in Rumania even later.

Geology.—Petroleum, in one or other of its many forms, has been found to appear in all the principal divisions of geological time, though perhaps the evidence of its discovery in rocks of pre-Cambrian age is somewhat vague. The principal deposits, however, such as those of Southern Russia and the Eastern United States of America, are obtained from the Carboniferous (Upper) Palæozoic age, or from the Tertiary system, as in the Caucasus, California, Galicia, and Rumania, the rocks of Mesozoic age giving rise to comparatively small deposits.

No connection has as yet been shown to exist between the existence of petroleum deposits and the present limits of land and sea. It is a curious fact, however, that the principal deposits are intimately associated with mountain ranges; and, as will be seen from what follows, this is probably more directly due to the fact that it is in the neighbourhood of mountains that the strata have been contorted into a form suitable for the accumulation of the oil.

In order that an accumulation of oil may be possible, one form of stratification is essential, namely, a rock sufficiently porous to serve as a sponge or reservoir-rock to hold the oil, overlain by a layer of impervious rocks to prevent the displacement of the oil, or its evaporation or oxidization. The principal porous rocks are sandstones, conglomerates, and limestones, sandstones being the best known. The commonest covering rock is clay or shale, of fine-grained structure. In order that an oil-deposit of any magnitude can exist, this sandwich-like stratification is necessary, and the non-existence of payable deposits in many districts where the signs appear favourable is probably due to the fact that the impervious cover overlying the porous rocks has become faulted and fractured.

In addition to this stratification, a certain conformation of the strata is also required. Experience shows that an undulating formation is necessary for the formation of an extensive oil-field, the oil always collecting (as a result of its low specific gravity) in the anticlines. A terrace-formation, which may be regarded as a modified form of anticlinal, is also eminently suitable.

Some information as to the capacity of the various oil strata to contain oil may be interesting. Experiments have shown that an oil-bearing rock of coarse-grained conglomerate may contain up to 1 per cent. of its bulk of oil,* and the phenomenally rich oil-sand of the Russian fields in the Baku district has [redacted]

drilling whether gas or oil will be struck first; and the writer has seen cases at Boryslaw (Galicia) where the pressure of the escaping gas from a well in which the oil had not been struck was so great as to render it impossible to let in a heavy sand pump, and the drilling was of necessity shut down until the gas had become somewhat exhausted. Several theories have been propounded to account for this pressure, the two generally accepted being:—

(1) That it is due to hydrostatic pressure, caused by percolating water entering the oil strata at its outcrop.

(2) That it is due to gas gradually accumulating without opportunity to escape (owing to the impervious covering), and thus being brought into a highly compressed state.

It has already been remarked that the American petroleum industry owes its origin very largely to the discovery of petroleum in brine-wells; and it may be here stated that an intimate connection appears to exist between salt, petroleum, and natural gas, since throughout all oil-fields of the world the hydrocarbons are found in close association with salt, either in solution or in the solid state. Salt, however, frequently occurs without petroleum.

It does not fall within the scope of this paper to touch upon the various theories put forward to account for the origin of petroleum, which include the important subject of its aggregation; and this short account of the general geology of petroleum may be fitly ended by quoting remarks by Dr. Orton, in reference to the oil-fields of the United States of America. Dr. Orton says: "Different fields have different sources. We can accept without inconsistency the adventitious origin of the oil in the Pennsylvanian sandstones, and its indigenous origin in the shales of California, or in the limestones of Canada, Kentucky, or Ohio." *

Oil "Shows."—A district generally comes to be known as an oil-field because the inhabitants of the locality have noted and made use of certain "shows," which have probably been known to exist for many years, or even centuries, before they attracted serious attention. Very common shows are escaping gas, or exuding oil, the latter being found to collect in hollows or on the surface

* *Report on the Occurrence of Petroleum, Natural Gas, and Asphalt Rock in Western Kentucky*, 1891, page 43.

of streams. Again, deposits of asphalt are met with covering in some cases many acres, and so on. The inhabitants spread accounts of these shows, which attract attention commercially, and so the district comes to be reported on and active work is undertaken. Expert advice is necessary in order to locate further operations, for, as is clear from what has been said on the subject of petroleum geology, where the shows abound, oil in paying quantities need not necessarily exist. The shows generally arise from oil escaping from the reservoir-rock at its outcrop, or else along faults in the impervious covering; and on the integrity of this impervious covering depends the value of the deposit. Naturally, however, shows have a decided value, because they usually indicate surface or small deposits, and where the stratification and geological formation is favourable, these surface-deposits very often cover the big paying oil which is found at varying depths below. In this connection it may be as well to quote a favourite saying of practical oil-men, namely: "The only real expert is the drill." No man living can say with absolute certainty that a formation capable of containing oil will contain oil, but it is possible to say with certainty that some formations cannot repay working.

Winning the Crude Oil.— Having selected the site on which to commence operations, there are two ways in which the oil can be extracted from the reservoir rock. One is by digging a shaft down to the oil strata, and the other is by drilling a well. Dug

[redacted]

the bottom. The débris was wound up by buckets on a hand-winch, which afterwards served for raising the oil that collected at the bottom of the well when finished.

The whole outfit was of the crudest description, and the conditions under which the men worked were usually deplorable, fatal accidents as a result of earth-falls, fire, or gas poisoning being common. Petroleum-gas affects its victims in a curious way, at first making them apparently intoxicated, so that they sing and dance in a frenzied manner, until they suddenly collapse; and when once this happens, recovery is rare.

Dug shafts may be seen in operation at the present day on the oil-field of Bustenari (Rumania), and, when visited by the author three years ago, they continued to yield handsomely; some new shafts were even then being dug. Naturally the conditions of working on this field nowadays are better than those described above, and the winding of oil from the shafts is generally done by horse power. The chief feature about these shafts is their cheapness, and when such shafts could reasonably be expected to reach oil at shallow depths, their employment might be advocated even nowadays, both on that score and on account of the valuable information which they yield as to the geological formation of the district in which the work is being carried on. Naturally the oil raised in buckets from these hand-dug wells is mixed with much water and dirt, and is separated by settlement in tanks.

Regarding the drilling of wells, which is for all practical purposes the only means adopted for tapping oil-supplies at the present day, the system in universal use is some form of percussion drilling. Rotary drills have been used, as, for example, very largely in the Texan fields; but their employment in oil-field practice, so far as is known to the author, is confined to that district, and the results obtained do not appear to have been highly satisfactory.

The forms of percussion drill in general use are:—(1) The Canadian pole system; (2) the American rope system; (3) a combination of rope and pole system; and (4) water-flush drilling with either right or left-handed flushing. The first three are the so-called "dry-drilling" systems.

It is impossible within the limits of this paper to enter into a full description of these systems, and, moreover, it is perhaps hardly necessary, inasmuch as the general principles adopted

in artesian-well drilling are commonplace. Whereas, however, ordinary bore-holes for water and prospecting purposes are not usually carried to any very great depth, oil wells 3,000 feet deep are common. Depths of nearly 4,000 feet are not infrequently met with, and these with a diameter of 5 inches at the bottom. Consequently, it will be advisable to briefly describe one system, as adapted for deep-well drilling, and then point out equally briefly the points of differentiation in the other systems.

Canadian Pole System.—The drill is a heavy iron chisel known as a "bit," the weight and effective striking force of which is increased by means of a heavy iron bar termed a "sinker," to which it is screwed. This combined bit and sinker is suspended by a string of wooden poles* screwed together from the end of a massive beam of wood known as a "walking beam," pivoted at its centre, its other end being connected by a connecting-rod to a crank on a shaft driven by a horizontal engine varying from 12 to 30 horsepower. The effect when the engine is running is for the bit to be raised up and down. Now comes into play a tool known as "jars," without which the whole scheme of operations would break down. The jars may be likened to two links of a chain, and their place is between the sinker and bottom pole of the string. The length of the string of poles is so adjusted that the bit at the top of its stroke is well clear of the well-bottom, but at a height less than the total stroke. [redacted]

valve at its lower extremity, let in on a rope. All tools and poles are provided with a pin at one end and box at the other, with conical threads.

When the driller thinks that the bit is getting blunt, or has cut too much rock to enable it to work properly, the link between the walking-beam and the crank, known as the "pitman," is unshipped, the walking-beam swung back, the drilling-rope with swivel-end let down, and the rods pulled up and unscrewed one by one. Means are provided on the crank for altering the length of stroke, according to the nature of the rock that is being cut; and by an ingenious arrangement of an endless cord, known

FIG. 12.—CHARACTERISTIC VIEW OF A PART OF AN OIL-FIELD, SHOWING A DISMANTLED DRILLING-RIG IN THE FOREGROUND.

as a "telegraph," the throttle on the engine is under the control of the driller at the well-mouth, so that the speed of running can be easily controlled.

As to surface installation, the main feature is the derrick, from 40 to 50 feet high, necessary for handling the long tools. Figs. 1 and 2 (plate xxi.) give an idea of the general arrangement of a Canadian rig and draw-works. Figs. 3 to 7 show different forms of bits; figs. 8 and 9, jars; fig. 10, one wooden pole of a string; and fig. 11, a sinker. In figs. 1 and 2 heavy leather or hair belts connect the wooden wheels on the main shaft to the drilling-rope spool and sand-line spool respectively, and the levers (shown handily placed for use of the driller on the floor

of the derrick) actuate the brakes, checking the run-out of rope from these two spools, and friction rollers tightening the leather belts for winding in. Fig. 12 is a characteristic view of part of an oil-field, showing a dismantled drilling-rig in the foreground.

American Rope System.—Here precisely the same principle is adopted, with somewhat different appliances. The cutting tool, or sinker (or as it is known in American parlance, the "anger stem") and jars are suspended by a long manilla rope, going through a temper-screw to a sheave in the crown of the derrick (70 feet high, and much higher than the Canadian derrick), and thence down to a drum behind the driller standing facing the engine. The temper-screw is carried at the end of a walking-beam, and serves for lowering the bit as the work proceeds. Some American drillers occasionally dispense with jars altogether (which is impossible in the pole system), and, relying on the elasticity of the rope itself, carry out their work most effectively, this process being known as "bouncing the bit." The advantage of the American system is that the bit is removed, when necessary, much more expeditiously than is possible with the Canadian rig.

Combined Pole and Rope System.—This system, as its name implies, is a mixture of the American and Canadian systems. The cutting tools, sinker-bars and jars are identical, but the tools are suspended from the walking-beam by means partly of [redacted]

Rotary Drilling.—This system is widely different from any of the preceding. The cutting is done by means of a circular tool, which is kept revolving. The calyx drills and various diamond systems are examples of this rotary system of drilling, and are quite well known. The detritus is removed from the bottom of the well by flushing; and, as has been said, this system of rotary drilling has not found favour amongst people interested in the winning of crude petroleum in the oil-fields of the world, with the exception of the Texas district.

Lining Wells and Shutting off Water.—Whatever system of drilling be employed, it is always necessary to line the well, in order to prevent cavings and the subsequent choking of the well, and, what is perhaps more important still, to shut off the water which is nearly always passed through during the course of drilling, and prevent flooding of the oil-bearing strata. As regards cavings, the trouble due to this cause may be very great in a disturbed formation, so that it is impossible to keep the bit more than a few feet ahead of the bottom of the tubes; or it may be so little in undisturbed rocks that hundreds of feet can be drilled out without any fresh casing being let in. As regards the necessity for shutting off water, it may be laid down as an axiom that water is to be kept out of the oil-bearing rocks, and great trouble and expense is often incurred in order to ensure this happy state of affairs. The work must be of a permanent nature, for the writer has seen cases where water has suddenly broken into a well which had been producing steadily for several years, and not only ruined the further production from that well, but also seriously damaged the yield from a number of wells in its vicinity.

It should perhaps be mentioned here that the general consensus of opinion on the part of oil-field managers is opposed to the employment of water-flush drilling, owing to the fact that its successful operation depends on the forcing of water into the bore during the whole course of drilling operations; and it is maintained that, as soon as the bit enters the oil-rock, a general watering must take place. Undoubtedly this often happens, but in the opinion of the writer, where oil is present under enormous natural pressure, as is often the case, the flooding is not to be feared, and flush-drilling can be employed with safety. A bitter controversy has raged for some years on this subject between ex-

ponents of the so-called dry and those of the flushing systems, which is to be regretted, because it is impossible to lay down any hard and fast rule as to the best system to be used in each and every case; each case must be considered on its merits.

Ordinary artesian screw-casing is usually employed, except that in unstable formations the thickness is increased to $\frac{3}{8}$ inch. In Russia, where the diameter of the wells is generally much larger than on other fields, the expense of this screw-casing would be prohibitive, and casing made of rolled sheet-iron, riveted, is used. Naturally in deep wells, several strings of casing are run in as the diameter gradually diminishes towards the bottom. When artesian casing is in use, the water is shut off by means of packings. With riveted casing, cement is let in behind; and although the water can thus be quite effectively shut off, the cost of doing so is relatively great.

"*Fishing.*"—It must not be supposed that the drilling of an oil-well is a simple and straightforward task. The delays due to tools breaking and breakdowns of all sorts are many and vexatious, and the ingenuity displayed by the drillers in fishing broken tools out of wells, pulling out casing which has collapsed under the pressure of the formation, and attending to the hundred-and-one things that are always cropping up, is remarkable.

Raising the Oil when Struck.—The processes briefly described above are intended for tapping the oil-supplies, and there now [redacted]

is done generally by pumping the well or by baling, and in some cases a compressed-air lifting arrangement is adopted. Pumping is the most economical system, and is employed wherever possible. A pump-tube, 1½ to 2½ inches in diameter, is let in at the bottom of the well, the end being composed of a barrel with sieve and valves. The valves are steel balls on brass seatings, and the plunger is packed with leather rings. The plunger is worked by means of a wooden or iron rod coming up inside the tube. By means of an ingenious arrangement of angle-pieces at the well-mouth, the vertical movement of the pump-rod is converted into a horizontal movement, and the horizontal rod, "jerker-line," as it is called, connects the pump with a central installation known as "pump-rig" supplied with a boiler and engine actuating a "rocking wheel," to which numbers of jerker-lines are attached. The engine keeps this rocking wheel oscillating about a quarter of a revolution in a horizontal plane, and thus as many as twenty to forty, or even more, wells can be pumped from one power-station.

Naturally, the number of wells which a pump-rig can work depends on their depth and the consequent heaviness of the pump-rods, also on their distance from the source of power. The life of the pumps varies according to the nature of the crude oil raised. If much water be present, the leather cups forming packings on the plunger rapidly deteriorate; and, if the oil be found to contain sand in any quantity, pumps are unusable, owing to the fact that these leather cups become almost immediately destroyed. That is why baling is almost universally employed throughout the Russian oil-fields, where the oil-bearing rock is either sandstone or sand, and the crude oil contains a large quantity of sand in either case. The baler is practically identical in principle with the mud-pump employed for raising detritus cut during drilling operations, and is run in on a rope, fills automatically, is withdrawn, and the crude oil contained in the barrel runs into a tank by the well side. Obviously, baling is much less economical than pumping, as one man is required to bale each well, and a complete outfit is necessary at each well for the purpose, as compared with one source of power and at most two men in charge of a pump-rig pumping a number of wells. As a consequence, it frequently pays to pump wells producing as little as a barrel or two a day, whereas where baling is necessary only comparatively big producing wells prove paying.

As to the air-lift arrangement, in use in some of the Russian oil-fields, it is expensive to instal, and its efficiency in practice is often questioned. As a result, its adoption is by no means general.

All wells are provided with one or more small storage-tanks of either wood or iron, capable of holding from 10 to 40 tons, into which the crude oil, however raised, is run. A network of pipe-lines connects these tanks with the main pumping installation, and wherever possible gravity is made use of for running the oil from these small tanks to the pumping-station, whence it is either shipped or pumped into large storage tanks.

Storage and Distribution.—Crude oil is usually stored in tanks made of boiler-plate, a common size being 90 feet in diameter by 30 feet in height, giving a capacity of about 2,500 tons. Larger tanks up to 5,000 tons are met with. They are provided with manholes near the bottom for cleaning purposes, and one or more hatches in the roof, with well-fitting coverings, a suitable gate outlet-valve for oil, and a blow-off valve for water. According to the regulations of the mining authorities in some oil-fields, lightning-conductors are insisted upon; in other places their provision is left to the option of the tank owners, and some doubt appears to exist as to whether the addition of conductors really lessens or adds to the danger from lightning.

In some places, earth-storage has been much used, reservoirs [redacted]

trunk-lines. This is a conical steel wire-brush, provided at the end with a stiffened leather base, and is pumped through with the oil.

In the United States of America the pipe-line system has been brought to a high state of organization, the oil being pumped from the inland producing regions, over hundreds of miles to refineries situated on the sea-board. Of course, in a long pipe-line a relay-system is employed; for example, on the New York line there are eleven pumping-stations, each with a pump-house and two or more tanks. In other countries, however, owing to topographical and other considerations, other means of transport are used, the most common being by means of railway tanks. This is a cylindrical tank of boiler-plate, with a dome through which it is filled, and a valve underneath for outlet. These are common objects on all railways.

Where possible, water-transport is made use of, owing to decreased freights. Tank-barges 100 to 150 feet long, of 20 feet beam, and of varying draught, divided into a series of compartments by oil-tight bulkheads, provide a convenient transporting medium where water-communication is available.

Depths and Diameters of Wells.—Great variations in the depths and characters of wells in the various oil-fields of the world are to be observed. As a general rule, the depth is found to increase with the age of the field. This is a natural consequence of the fact that in most cases more than one oil-bearing rock is present; and, as the upper ones become exhausted, wells are drilled deeper in the hope, often realized, of reaching fresh supplies. Again, from what has been said about the geology of oil-fields, it is seen that the situation of the well with regard to the axis of the anticline has an important bearing on the depth. All these points being considered, however, it remains a fact that in some districts paying oil is struck at much shallower depths than in others. For instance, in Canada the wells average in depth about 1,000 to 1,500 feet, whilst in Pennsylvania and the Eastern American oil-fields the depth is from 2,000 to 3,000 feet. In Baku, in Russia, a few years ago a well of 1,000 feet was considered deep: nowadays this depth is often exceeded in this same field. In Grosny, a field attracting considerable attention in Russia at the present day, visited by the writer a

few months ago, paying oil was raised from depths of 700 to 800 feet; but here, also, the gradually increasing depth of new drillings was most marked. In Galicia, in the famous Boryslaw-Tustanowice field, depths up to 4,000 feet are not uncommon.

The diameter of a well is governed by the nature of the crude oil, and the means necessary to raise it. This refers naturally to the bottom diameter, or the diameter of the last string of casing inserted. The size of the well at the commencement of drilling depends on the desired diameter at the bottom and the depth to which the well has to be drilled. Wells which will have to be baled are naturally much larger than those which can be pumped; and in the case of pumping-wells, those producing a thick and heavy crude oil should be larger than those from which a light, thin oil is obtained.

Upkeep and Life of Wells.—It has been stated authoritatively that the average life of an oil-well is about five years. Whilst this statement may be accepted, the fact remains that many wells continue to produce for a much longer period than this. The writer has had control of wells (pumpers) which were more than thirty years old, and still paid to pump, though, of course, this is exceptional. Again, many wells became exhausted in a few months. An even more curious case has been observed in a well drilled by the author at Mraznica, where, during the course of drilling operations, the well several times spouted, throwing

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of wax sometimes form, completely stopping up the hole. Again, as the production falls, deepening a few feet may have a most beneficial effect; or the well may even be drilled down a considerable distance to a lower oil-bearing rock.

In some fields, especially in America, a regular practice on completing the drilling of a well is to "torpedo" it. A charge of nitro-glycerine is placed at the bottom of the well and below the casing. The well is then partly filled with water and the charge fired, and a large chamber is blown out of the rock at the bottom.

Gas.—It has been remarked that the oil is often accompanied by greater or less quantities of gas. This can be made use of for firing boilers, and running explosive-engines in pump-rigs, and so on, and can be of valuable assistance in effecting working economies. At the same time, this gas is a great source of danger in an oil-field, on account of its being highly inflammable and when mixed with air violently explosive. Nearly all the fires, often attended by considerable loss of life, which sooner or later visit all oil-fields, are attributable to the gas; and the strictest regulations covering the use of lights, smoking, and the situation of boiler-houses with regard to the wells, have to be insisted on.

Production of Individual Wells.—There is no law governing the possible production of a well drilled in unknown territory. In the early days of the petroleum industry in the United States of America big fountains were brought in, and the general rule was for all wells to be gushers. It is in Russia, however, that the biggest fountains have been met with, one notable well brought in in 1875 yielding as much as 600,000 gallons a day, most of which ran to waste, whilst several wells yielding several hundred thousand gallons daily for considerable periods have been bored.

The life of these fountains is limited. As the pressure on the oil diminishes, the violence of the outflow decreases: gradually the well ceases to flow naturally, and it has to be pumped or baled. As a matter of fact, the value of an oil-field is not measured by the quantity of oil thrown out by fountains, but by the length of time during which a steady supply of crude oil can be artificially raised, which should extend over several

years. It may be remarked that big fountains, such as those brought in in the early days of the Russian industry, are no longer met with on any fields worked at the present day.

Cost of Drilling and Time taken to Drill.—This varies enormously in different fields, and depends on many circumstances. Sometimes, somewhat curiously, a deep well costs less than a comparatively shallow one; and, generally speaking, the diameter of the well has a greater effect on the cost than the depth—of course, within limits. The wide wells of Russia are very expensive, whilst the deep wells of Pennsylvania are relatively very cheap. In Russia, it takes from nine months to a year, or more, to put down a well from 1,000 to 1,500 feet, and in parts of America where the strata run almost horizontally, 1,500 feet can be drilled in about three weeks. Throughout Europe, however, where the strata in the oil-fields is more disturbed and difficult to work in, it generally takes not less than five or six months to drill 1,500 feet, and about a year to go down to 3,000 feet.

Physical Character of Crude Oil.—The oil, as won from the wells, is not fit to be marketed. It has to undergo a process of distillation, and the distillate has to be subjected to subsequent refining, in order to produce the various mineral-oil products met with in commerce. It is not within the scope of this paper to deal with this portion of the petroleum industry, however briefly; but it

[redacted]

Shale-oil Industry.—There is one method of producing oil that has not yet been touched on, and yet is worthy of note if only because it is the sole way in which the paying oil is produced in the United Kingdom. Reference is here made to the Scottish shale-oil industry. A bituminous shale is mined and subjected to distillation in retorts, a crude oil being won, which is afterwards further treated and various commercial products are produced from it. Mention was made earlier in this paper of the discovery of Young's process in 1850, and the very considerable industry carried on in Scotland at the present day is the result of the discoveries made at that date.

Deposits of bituminous shale have been discovered in other parts of the world, notably in Australia, and it appears likely that an important shale-oil industry will soon exist in that continent. Nevertheless, in spite of the increasing quantities of oil thus produced and the importance of the shale-oil industry locally, its effect on the petroleum industry of the world is quite negligible, and for all practical purposes it may be said that all oil is mined in the manner so briefly described in this paper.

Mr. A. Beeby Thompson (London) wrote that there was one point raised by the author of the paper, when dealing with the saving of oil, which had always been the subject of much scientific controversy, namely, the "air-lift." This system had fallen into disrepute in certain quarters in the Russian oil-fields through attempts to attain the impossible, but where it had been installed in suitable wells the benefits derived from its employment had been unquestionable. In petroleum-fields, whenever drilling difficulties had been encountered, and where pumping was impossible owing to the presence of sand suspended in the oil, the final size of the well might be only 6 to 8 inches in diameter, consequently only a 4-inch to 6-inch diameter bailer could be used, and the maximum production was small. If the quantity of liquid exceeded 50 per cent. of the depth of the well, such a well could be efficiently worked by an air-lift; whilst, if the liquid exceeded 60 per cent. of the depth, highly efficient results could be obtained. As with the application of the air-lift to water, the efficiency quickly dropped if the level of liquid fell below a certain point. In practice it

was usual to admit air to the rising-main at a point which would secure always a 60-per-cent. submergence; but, if a fall of liquid were suspected, this amount should be exceeded where possible. With 60-per-cent. conditions of submergence it had been possible to raise 1 cubic foot of liquid to 11 cubic feet of free air, which worked out as efficiently as many types of pumps. The pressure of air had nothing to do with the action of the air-lift, but was just sufficient to overcome the head of liquid against which it pressed (the submergence) to obtain admission to the rising-main and the friction of the pipes. With a 50-per-cent. submergence, when 1 volume of liquid was raised to 25 volumes of air, a total efficiency of over 25 per cent. had been obtained in raising oil by air-lift from a well 1,500 feet deep: the efficiency being the ratio of theoretical power needed, to raise the liquid from the level in the well to the surface, to the indicated horsepower of the steam-engine driving the compressor.

The great value of the air-lift was in cases where the diameter of the well was too small to allow efficient bailing, and the percolation of a little water and accumulation of sand necessitated constant bailing from the bottom, to avoid the formation of a plug, which would exclude the entry of oil. Under such circumstances, a well which gave only 5 tons of oil daily, with a daily fuel-consumption of about 1·5 tons of oil, had by the air-lift process yielded 150 tons of oil daily with a daily fuel consumption of 2 to 2·5 tons of oil. In the Russian oil-fields, there [redacted]

one of the chief reasons why the air-lift system had not been more generally adopted. It was quite undisputed that, under suitable conditions, the crude oil could be raised from the well by the air-lift system with great success; and, given a well of small diameter (the other conditions still being suitable), more oil could be raised per day by that system than by baling. The necessity, however, of having the conditions suitable in order to obtain anything like efficient results, coupled with the comparatively heavy initial expenditure for air-compressors and air pipe-lines, together with the necessarily fairly heavy expense of upkeep, had, in his (Mr. Chambers') opinion, prevented the general use of the system.

Generally speaking, it was not good practice to have more than one system of raising the oil on any one mine. Hence, as a practically complete baling apparatus was existent at the well-mouth at any moment during the course of drilling, and as by baling, the oil could be raised under all conditions, without any necessity for adjustment, it had been found in general practice that, in fields where pumping was impossible and flowing wells were non-existent, baling was the most efficient system to employ.

The PRESIDENT (Mr. C. E. Rhodes) moved a vote of thanks to the author for his paper.

Mr. JAMES BARROWMAN (Hamilton) seconded the vote, which was cordially adopted.

Mr. FREDERIC KEFFER's paper on "Mining in the Boundary District of British Columbia" was taken as read, as follows:—

MINING IN THE BOUNDARY DISTRICT OF BRITISH COLUMBIA.

By FREDERIC KEFFER.

Topography.—Entering the Kettle river on the International boundary between the United States of America and Canada is a small stream which for this reason is called Boundary Creek. The territory adjacent to this creek is known as the Boundary district, and, generally speaking, includes the country between the northern fork of the Kettle river on the east and the main river on the west, extending some 25 miles north of the International boundary. The country, although mountainous, is not rugged, the hills seldom reaching a height of over 6,000 feet. Deep erosion and glaciation has rounded the contours and covered the surface with a deep layer of soil and drift, making prospecting somewhat difficult. All the more important mineral deposits so far discovered are in Canada, with the exception of the Lone Star mine, which is immediately south of and in contact with the boundary-line.

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greenstones (principally the latter) through the action of copper-bearing solutions. In the eastern portion, the ores are mainly volcanic ashes consolidated and largely altered through the action of copper solutions, while in the south, near the Lone Star mine, the replacements are in talcose schists, originally highly-altered eruptive basic rocks.

Porphyry dykes are the invariable accompaniment of the low-grade ores, their intrusion probably having afforded ingress for the mineralizing copper-bearing solutions.

Chemically considered, the ores may be classed as follows:—

Ores.	Basic.	Magnetites:	Fine-grained and massive, as in	Mother Lode mine. Sunset ,, Emma ,,
			Specular, as in	Knob Hill ,, Old Ironsides ,,
		Pyrrhotites:	Usually with some magnetite, as in	Mountain Rose ,, Senator ,, Morrison ,,
		Garnetites:	as in	Oro Denoro ,,
		Calcites:	Along limestone contacts, as in	Mother Lode ,, Emma ,,
		Pyrites:	In Mother Lode and many other mines.	
	Acid.	Highly siliceous altered lime-products, occurring in most of the Boundary mines.		
		Quartz, with ores of copper, disseminated through talcose schists, as in the Lone Star mine.		
		Quartz, with zinc blende, galena, and pyrite, as in (These are all narrow veins with high gold and silver values.)		Providence mine. No. 7 ,, Skylark ,, Strathmore ,, and many others.
		Quartz, with arsenical pyrites, as in		Athelstan mine. Iron Clad ,, Bay Horse Fraction.
	Neutral.	Altered volcanic ash, tuff, etc., impregnated with copper minerals, as in most of the mines of Phœnix, for example		Knob Hill mine. Old Ironsides ,, Snowshoe ,, Raw Hide ,, Gold Drop ,, Monarch ,, Idaho ,, and many others.
		Altered eruptive rocks occurring near limestone contacts, as in		Mother Lode mine. The "B. C." ,, Big Copper ,,

Of these classes of ores, the neutral constitutes by far the largest group, and, as the basic and acid ores may be suitably combined, the ores of the camp as a whole are self-fluxing and require no barren fluxes, the use of which would be prohibitive in any event, owing to the already low grade of the ores.

Composition of the Ores.—The following partial analyses illustrate in a general way the composition of the different classes of ores: —

	Silica. Per Cent.	Iron. Per Cent.	Lime. Per Cent.	Sulphur. Per Cent.
Basic Types:				
Emma mine	12·60	46·10	11·30	1·00
Mountain Rose mine	11·80	38·60	9·80	24·70
Oro Denoro mine ...	29·10	22·10	22·90	1·75
Acid Types:				
Lone Star mine ...	49·80	8·82	2·30	7·58
Providence mine ...	88·60	2·50	2·60	1·80
Athelstan mine ...	40·00	14·80	1·10	—
Neutral Types:				
Mother Lode mine ...	32·26	16·41	20·27	2·92
Snowshoe mine ...	34·30	12·86	18·43	2·56

The alumina in these ores ranges from 0 to 15 per cent., an average being about 8 per cent. Where the sulphur is as low as 3 per cent., it is needful to supplement it by the addition of ores like those of the Mountain Rose mine. The calcium is present as silicate, and also as calcite. The latter, which is a constant constituent of the low-grade ores, greatly assists in the smelting, tending to break up the big pieces of ore when subjected to heat. For this reason, coarse-crushing only is necessary, a small saving in costs being effected.

Occurrence.—In the narrow high-grade veins, the walls are quite definite, but in the low-grade deposits the reverse is usually the case, the ore fading away into the surrounding country rocks.

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Probably at no other place in the world are ores containing sometimes as low as 1 per cent. of copper successfully mined and smelted without any previous concentration. The Boundary ores contain from 1 to 3 per cent. of copper, the average being not far from 1½ per cent., besides which they carry from 4s. to 12s. (1 to 3 dollars) in gold and silver, an average being about 6s. (1½ dollars). These values are principally in gold, the silver averaging about ⅓ to ½ ounce per ton.

Why the profitable handling of such ores is possible may be briefly summarized as follows:—

(1) The immense size of the low-grade deposits makes mining on a vast scale possible.

(2) The exceptional solidity and firmness of the ground, which, though easy to drill and blast, nevertheless stands well, renders the opening of great stopes without timbers both practicable and safe.

(3) The chemical composition and physical structure of the ores renders them "self-fluxing" and easy-smelting, so that furnaces run fast and have great capacity per square foot hearth-area.

(4) The proximity of the great fields of coking-coal in the Crows Nest Pass makes a comparatively low-priced fuel obtainable.

With any one of these four conditions lacking, it would not be possible to mine and treat the ores at a profit on a normal market of, say, 7½d. (15 cents.) per pound for copper. Other contributing and favourable conditions in the order of their importance are:—

(5) An abundant and low-priced electric power from the Bonnington Falls, 80 miles distant, on the Kootenay river.

(6) A plentiful timber supply.

(7) Dry mines, requiring little pumping.

(8) An unsurpassed climate, making for the health and comfort of all engaged in the work.

The district is served by the Canadian Pacific and the Great Northern railway systems, and locally by the Kettle Valley lines.

Mining Operations.—In the earlier history of the camp, the greater portion of the ore was mined from great open-cuts, or "glory-holes," as they are locally termed. In most of the larger

mines, these open-cuts have been carried to the limits of safety, and the tonnage from open-cut mining is steadily decreasing. The method followed is simple:—The soil and surface rock (if leached and barren) having been removed, a tunnel is driven in the hill under the deposit, and one or more raises are run to the surface through the ore near the foot-wall. These raises are of large section, and are fitted at the bottom with heavy-timbered chutes. The raises having been filled with broken ore, funnels are started at their tops, the slope being kept at about 45 degrees, so that the ore will run by itself into the raises without any shovelling.

When the work has been carried as deep as safety warrants, the sides of the funnels are cut away until the walls of the ore or adjacent funnels are reached: but in this stage of the work more and more shovelling has to be done as the slopes grow flatter. It will be apparent that the greater the dip of the ore-body the deeper can the glory-hole be carried without danger from the hanging-wall; also that, if possible, the tunnel should be driven so that the intersection of a vertical line from the outcrop of the hanging-wall with the foot-wall will be above the tunnel-roof. Fig. 1 (plate xxii.) illustrates the growth of a glory-hole.

When the breaking-down of ore at the top of a raise is first started, the holes must only be drilled 5 or 6 feet deep, but as the opening enlarges the holes may be drilled as much as 20 feet deep. These are chambered by exploding a few sticks of dyna-

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the raises. In other cases, as at the Oro Denoro mines, the ore is loaded by hand into low and broad flat cars, these being taken to raises for dumping.

As may be surmised, mining costs for quarrying in "glory-holes" are low, ranging with conditions from 2s. (50 cents.) to 4s. (1 dollar) per ton, which cost includes stripping and all other expense up to the time when the ore reaches the crushers. Figs. 2 and 3 (plate xxii.) show in section and plan a worked-out glory-hole with stope underneath. The necessity for occasional pillars to support the hanging-wall of deep glory-holes is rendered imperative by the subsequent stoping operations, in which the ore next the hanging-wall between the pillars is extracted.

Stoping.—In opening a stope, it is the usual practice to run one or more drifts under the ore-body to be extracted, the number depending upon its width. This done, short raises are run at intervals of about 30 feet to a height of 10 to 12 feet above the roof of the drift, the raises being provided with timbered chutes at the bottoms. From the tops of the raises, stopes are started and continued laterally until all the ground above the raises is connected in one great stope. The work is then carried up to the next level above, the men standing on the broken ore, only the excess being drawn from the chutes.

A raise must be provided from some point in the stope to the level above for ventilation, and also one or more manways must be kept open for access to the work. As the men work on top of the broken ore, they are always near the roof, and are thus able to keep close watch for bad ground. Accidents from falls of roof are exceedingly rare in the district. If the stope be very extensive, pillars are maintained at suitable intervals for support of the roof. Manways are conveniently made in these pillars, or in the barren rock of the walls. The ore must be bulldozed as it is broken down, so as to avoid clogging the chutes with large blocks. When a stope has been carried to the level above, the ore is drawn as circumstances dictate; but a stope should not be drawn until that portion of the mine is to be abandoned, so that pillars, etc., may be robbed as much as possible while the drawing of the stope is in progress. It is inevitable that with this method of mining, a large amount of capital is tied up in the form of broken ore in the stopes. This, however, cannot be avoided, as timbering is out of the question on account of the

expense. As an offset, however, the men are safer when working on rock, and the holes can be drilled deep and great masses of ore broken down at a time when if broken down on timbers the ore would crush them. In cases where the dip of the ore is low, in addition to the drifts run in the ore, one or more others must be run in the barren foot-wall and raises made to the ore above, otherwise the ore could not be drawn without shovelling. Fig. 4 (plate xxii.) illustrates a case of this nature.

In some instances, the sill floor is timbered and chutes provided at intervals, after which the ore is broken down on the timbers to the level above. Owing to the cost of timbers heavy enough to support the great weight, this method is not advisable, save for small bodies of ore. In other cases, timbered ways are built on the sill floor, and provided with chutes, the ore being broken down around and above them (fig. 5, plate xxii.). Again, as in the Emma mine, where the ore is vertical, a central drift is run in the ore and is roofed with heavy stulls and lagging. The stope is then carried up in a V shape until the walls are reached, and most of the weight of the ore broken down is thus supported on solid rock (fig. 6, plate xxii.). As may be supposed, vertical ore-bodies present much fewer difficulties to the miner than the inclined ones.

Ore-handling.—At the Mother Lode mine, all the ore is hoisted through a four-compartment shaft, the compartments measuring $4\frac{1}{2}$ by 5 feet. Two are used for the skips, which hold from [redacted]

crushers the ore passes over a 3-foot wide conveyor-belt to the railway-bins some 200 feet distant. The skips are handled by a 200-horsepower double-drum steam hoist-engine. The air-compressor plant consists of an Ingersoll-Sergeant piston-valve machine of 3,200 feet free-air capacity per minute, and of a Canadian-Rand compressor with a capacity of 3,400 feet of free-air per minute, the first machine being driven by a 500 and the latter by a 600 horsepower motor. All steel is sharpened on a drill-sharpening machine, thus furnishing drills of uniform size, as well as doing work which stands better in drilling than hand-sharpened steel. Skip and crusher chute-gates are of the finger type, made of railroad iron, and are handled by compressed air. Speaking-tubes connect the skip-loading stations with the hoist-room, in addition to the usual bell-lines.

In the Mother Lode mine, the haulage of cars is done by horses, these pulling trains of four cars each. In the Granby mines, the haulage is mainly done with motors and steam-engines, the distances traversed being greater. There are in these latter mines two tunnels connecting with the stopes, at the entrance to which are located railway-bins and crushing-plants, the crushers being of the size of the larger one in use at the Mother Lode mine. The deeper workings are reached through a three-compartment incline shaft, the ore or waste being hoisted to the top of the head-frame, where it dumps into a small bin, which can be rotated so as to dump either into waste or ore-bins at will. From the ore-bins, which are located on either side of a giant crusher, the ore passes to the crusher and thence over a conveying-belt to the ore-bins at the railway. In the Snowshoe, Rawhide, and some other mines, the ore is not crushed, but is shipped direct to the smelters.

Electric Power Plant.—Electric power has practically displaced steam in the Boundary district, except in isolated instances. Power is furnished by the Cascade plant situated some 25 miles distant from the centre of the district, and by the West Kootenay plant, 85 miles distant. The former plant is located at the falls on the Kettle river, and can generate at low water from 2,000 to 3,000 horsepower, which is sent over the lines at a pressure of 20,000 volts. The latter plant can generate from 12,000 to 15,000 horsepower, and the power available at the falls is said to be, at low water, 60,000 horsepower. The

line-voltage at present is 40,000 volts, although arrangements are made for bringing this up to 60,000 volts should occasion require.

Output of the Boundary District.—Eleven years ago the Boundary district was practically a wilderness, remote from the nearest railway, and reached by trails or poor roads. Its growth and development can be best measured by the output since shipping began, shown in the following table; but this comprises only ore smelted at the three local smelters, and does not include a considerable tonnage shipped to the Trail and Nelson smelters.

Year.	Tons Smelted.	Year.	Tons Smelted.
1900	62,389	1905	982,877
1901	348,439	1906	1,172,430
1902	460,940	1907	1,133,017
1903	697,404		
1904	837,666	Total	5,695,162

The PRESIDENT (Mr. C. E. Rhodes) moved a vote of thanks to the writer of the paper, which was carried unanimously.

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WINDING-ENGINE TESTS, WITH NOTES AND SUGGESTIONS ON THE DESIGN AND TESTING OF PLANT.

BY S. L. THACKER.

I.—INTRODUCTION.

The testing of power-plant, necessitating, as it does, the careful observation of many varying factors, presents a problem which depends for its successful solution upon the application of those first principles of all scientific investigation, namely, the standardization of the instruments employed and the correlation of the methods of independent observers. General principles, with detailed instructions for the testing of steam and gas power-plants, have been laid down by Committees of the Institutions of Civil and Mechanical Engineers, but it will be recognized that, in their application to the testing of winding-plant, some variation of method is rendered necessary, owing to the exceptional and peculiar conditions of working.

The winding-engine of a mine, owing to the intermittent character of its work, and the variation of power from zero to a maximum within a short period of time, presents difficulties in the economic utilization of steam and in the accurate recording of the results obtained, which are probably as great, or greater, than in the case of any other description of power-plant.

Much attention has been directed within recent years to the increase of economy in this direction, and various claims and recorded results have been put forward by the respective advocates of expansion-gear, compounding and electric winding, based on tests which, although they may have been made with considerable care, are largely inconclusive in their results, owing to the absence of the above-mentioned uniformity of method.

The writer's object in this paper is to record the results of his own investigations; to point out some sources of loss which, in his opinion, have hitherto received insufficient attention in their bearing upon the design and running of plant; and, finally, to suggest the lines upon which he considers all winding-engine tests should be carried out.

II.—General Theory.

Before proceeding to review the tests which have been made, it will be necessary to consider briefly the distribution of energy during the process of a wind, and to establish the formulæ by which the various dynamic forces may be expressed.

The total mechanical energy developed during a trip is converted from the heat-energy of the steam during the revolutions under steam admission, part of this total energy being utilized to raise the mean unbalanced load the distance corresponding to those revolutions, and part to give the necessary acceleration required to attain the maximum velocity. The latter portion is accumulated as kinetic energy in the moving masses. During the remainder of the trip, part of this energy is used in raising the mean load the remaining distance, and part is lost so far as useful effect is concerned, being again converted into heat at the drum-brakes, in friction, and in compression in the cylinders.

It has been asserted that, provided steam is shut off at such a point that the accumulated energy is just sufficient to complete the wind, no loss of effective energy will take place; but, on reflection, it will be evident that, for this to be possible, the plant would be required to run, during retardation, absolutely without friction, and without any resistance in the cylinders from compression or vacuum. Practically, this is, of course, impossible; and it will be shown that while the retardation-loss can be [redacted]

The total mechanical work for the complete wind may be evaluated as follows:—

For the distance, λ_t, the work against gravity equals:—

$$(F.P.)g_t=(L+\lambda_r \cdot w_f)\cdot \lambda_t \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

The energy developed in attaining velocity is compounded of that required to accelerate the total mass in vertical motion, namely, the ropes, cages, tubs, and coal, and also of that required to accelerate the mass in angular motion, namely, the pit-head pulleys and the winding-drum of the engine.

The former quantity may be expressed in foot-pounds as:—

$$(F.P.)a_1=\frac{Wv^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

where $\qquad W=L+2w_r+2w_c;$

and the latter quantity may be expressed as:—

$$(F.P.)a_2=\frac{W_d v_g^2}{2g}=\frac{W_d}{2g}\left(\frac{v.r_g}{r}\right)^2 \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

The total acceleration work therefore equals:—

$$(F.P.)a=\frac{Wv^2}{2g}+\frac{W_d v_g^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

and the total mechanical work performed in the time t, that is, during steam-admission, equals in foot-pounds:—

$$(F.P.)_m=(F.P.)g_t+(F.P.)a \quad . \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

Alternatively considered as an equation of moments, we have:—

$$(F.P.)g=L\cdot r\times 2\pi n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (7)$$

and $\qquad (F.P.)g_t=(L+\lambda_r.w_f).r\times 2\pi n_t \quad . \quad . \quad . \quad . \quad . \qquad (8)$

Let:—

$$I=\frac{Wr^2}{g} \quad =\text{moment of inertia of } W;$$

$$I_d=\frac{W_d\cdot r_g^2}{g}=\text{moment of inertia of } W_d;$$

$$\omega=\frac{v}{r} \quad =\text{maximum angular velocity};$$

then:—

$$(F.P.)a_1=\frac{I\omega^2}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

and $\qquad (F.P.)a_2=\dfrac{I_d\,\omega^2}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (10)$

therefore $\qquad (F.P.)_m=(F.P.)g_t+\dfrac{\omega^2(I+I_d)}{2} \quad . \quad . \quad . \quad . \quad . \qquad (11)$

Case 2.—Winding-rope balanced by Tail-rope.—The expression for the value $(F.P.)_g$ remains as before, but equations (2) and (8) become respectively :—

$$(F.P.)g_t = L \times \lambda_t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

and $$(F.P.)g_t = L \cdot r \times 2\pi n_t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

The equations expressing the values of $(F.P.)_a$ and $(F.P.)_m$ remain unchanged, except that the value of W is increased by the weight of the tail-rope.

Case 3.—Winding-rope overbalanced by a heavier Tail-rope.—The equation for the value of $(F.P.)_g$ remains as before, but equations (2) and (8) become respectively :—

$$(F.P.)g_t = (L - \lambda_r \cdot w_d) \cdot \lambda_t \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

and $$(F.P.)g_t = (L - \lambda_r \cdot w_d) \cdot r \times 2\pi n_t \quad . \quad . \quad . \quad . \quad . \quad (15)$$

where w_d equals the difference in pounds per foot of the weights of the winding and tail-ropes. The equations expressing the values of $(F.P.)_a$ and $(F.P.)_m$ remain unchanged, with the exception of the increase in the value of W.

Case 4.—Balancing by a Spiral Drum.—Although no test of a plant fitted with a spiral drum is included in this paper, the formulæ for this case are inserted here, in order to render the dynamical theory complete. Expressing all measurements in feet, let :—

r_l = maximum radius of the spiral drum.
r_s = minimum radius of the spiral drum.
r_t = radius on the ascending side at n_t revolutions.

λ_t = distance traversed by the ascending cage in t seconds.
λ_{t_1} = distance traversed by the descending cage in t seconds.

[redacted]

If the drum is so designed that the torque throughout the wind is constant, then the ratio between the maximum and minimum radii becomes :—

$$\frac{r_l}{r_s}=\frac{L+2w_c+2w_r}{L+2w_c} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (22)$$

The mean turning moment then becomes :—

$$M=r_s(L+w_c+w_r)-r_l.w_c \quad . \quad . \quad . \quad . \qquad (23)$$

and $$(F.P.)g_t = M \times 2\pi n_t \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (24)$$

If the ratio between the maximum and minimum radii is such that the torque varies throughout the wind, then the value of $(F.P.)g_t$ is better expressed in terms of the work performed on the ascending and descending sides, thus :—

$$(F.P.)g_t=(L+w_c+\frac{\lambda+\lambda_r}{2}.w_f)\lambda_t-(w_c+\frac{\lambda_{t1}}{2}.w_f)\lambda_{t1} \qquad (25)$$

And, by equation (24) :—

$$M=\frac{(F.P.)g_t}{2\pi n_t} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (26)$$

Owing to the very considerable weight of a spiral drum, and to the variation in the tangential velocity on the ascending and descending sides, the maximum angular velocity becomes the determining factor in the value of $(F.P.)_a$.

Let :—

$W_1 = L + w_c + w_r$ = weight on the ascending side.
$W_2 = w_c + w_r$ = weight on the descending side.
r_1 = drum radius on the ascending side at the attainment of maximum angular velocity.
r_2 = drum radius on the descending side at the attainment of maximum angular velocity.
ω = maximum angular velocity.

Then :—

$I_1 = \frac{W_1 r_1^2}{g}$ = moment of inertia of W_1.
$I_2 = \frac{W_2 r_2^2}{g}$ = moment of inertia of W_2.
$I_d = \frac{W_d r_g^2}{g}$ = moment of inertia of W_d.

therefore $$(F.P.)_a=\frac{\omega^2}{2}(I_1+I_2+I_d) \quad . \quad . \quad . \quad . \quad . \quad . \qquad (27)$$

and $$(F.P.)_m=(F.P.)g_t+\frac{\omega^2}{2}(I_1+I_2+I_d) \quad . \quad . \quad . \qquad (28)$$

Considering now the work performed in the engine-cylinders, we have the following equations of general application in all the preceding cases, let :—

$I.F.P.$ = total indicated foot-pounds.
P = mean effective steam-pressure.
A = net effective area of the cylinders, in square inches.
S = length of stroke, in feet.
N = number of cylinders.
D = equivalent effective diameter of the cylinders, in inches.
R = ratio of stroke to diameter.

Then, $I.F.P. = A \times P \times 2S \times N \times n_t$ . . . . . (29)

or $I.F.P. = D^2 \times \cdot 7854 \times P \times R \cdot D/6 \times N \times n_t$ . . (30)

And the mechanical efficiency of the whole plant equals :—

$$E = \frac{(F.P.)_m}{I.F.P.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (31)$$

The co-efficient of the friction-loss, therefore, equals :—

$$\mu = \frac{I.F.P. - (F.P.)_m}{(F.P.)_m} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (32)$$

And the kinetic efficiency, including the friction-loss, equals :—

$$\varepsilon = \frac{(F.P.)_g}{I.F.P.} = \frac{(F.P.)_g}{[(F.P.)g_t + (F.P.)_a](1+\mu)} \quad . \qquad (33)$$

Similarly, if T equals the total time of the wind, in seconds, and t, as before, the time under steam, we have for the indicated horse-power, the mechanical horse-power and the effective horse-power respectively :—

$$I.H.P. = \frac{I.F.P.}{t \times 550} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (34)$$

$$M.H.P. = \frac{(F.P.)_m}{t \times 550} = \frac{I.F.P. \times E}{t \times 550} \quad . \quad . \quad . \quad . \quad . \qquad (35)$$

$$E.H.P. = \frac{(F.P.)_g}{T \times 550} = \frac{I.F.P. \times \varepsilon}{T \times 550} \quad . \quad . \quad . \quad . \quad . \qquad (36)$$

After steam has been shut off, and during the retardation-period, part of the kinetic energy accumulated as momentum is reconverted into effective work in raising the net load over the remaining portion of the wind. The amount of this useful work may be evaluated, in the several cases considered, as follows :—

[redacted]

the maximum velocity reached during the wind, what is the maximum kinetic-efficiency theoretically possible? The value of v or ω determines, of course, the value of the quantity $(F.P.)_a$; and, if the whole of this energy is to be utilized in effective work and in overcoming the frictional resistance during retardation, then $(F.P.)_a$ must equal $(F.P.)g_r \times (1+\mu)$. Substituting this value in equation (44), we have, as a minimum,

$$(F.P.)_{KL} = (F.P.)g_r \times (\mu + \mu^2) \quad . \quad . \quad . \quad . \quad . \quad (45)$$

And the maximum theoretical kinetic efficiency will be:—

$$\varepsilon_{max} = \frac{(F.P.)_g}{(F.P.)g_t \times (1+\mu) + (F.P.)g_r \times (1+\mu)^2} \quad . \quad (46)$$

This efficiency cannot be realised in practice, owing, in the first place, to the impossibility of shutting off steam to such a nicety with a varying net load, and secondly, to the additional loss due to the cylinder-resistance during retardation. The question of the design of plant to run with the nearest approach to this theoretical efficiency will be discussed in Section VIII.

Reviewing the conclusions arrived at, we have:—

$$I.F.P. = \frac{(F.P.)_m}{E} = \frac{(F.P.)_g}{\varepsilon} = (F.P.)_m \times (1+\mu) \quad . \quad (47)$$

$$(F.P.)_m = (F.P.)g_t + (F.P.)_a = (F.P.)g + (F.P.)_{RL} . \quad (48)$$

$$(F.P.)_a = (F.P.)g_r + (F.P.)_{RL} \quad . \quad . \quad . \quad . \quad . \quad (49)$$

$$(F.P.)_{RL} = (F.P.)_m - (F.P.)g \quad . \quad . \quad . \quad . \quad . \quad (50)$$

$$(F.P.)g = (F.P.)g_t + (F.P.)g_r \quad . \quad . \quad . \quad . \quad . \quad (51)$$

$$(F.P.)_{KL} = (F.P.)_{RL} \times (1+\mu) \quad . \quad . \quad . \quad . \quad . \quad (52)$$

It will be seen from the foregoing argument that the accurate apportionment of the friction-loss, the kinetic-loss, and the effective work, in a complete test, presents a problem of some complexity. In considering the procedure to be adopted, the first difficulty which arose was the correct determination of the mechanical efficiency. With an ordinary continuously-running engine, this is by comparison a simple matter; but it has been shown, in the case of a winding-engine, that the expression for the mechanical efficiency (equation 31), includes the accumulated energy in the moving masses. The amount of this kinetic energy, being a function of the total weight and of the square of the velocity, depends, in part, upon the weight of the drum and its moment of inertia or radius of gyration (equations 4 and 10). Assuming that the weights of all the other factors are accurately known, the weight of the drum, unless determined at the time of erection, is

a matter of estimation; and, even if the weight is known, the location of the radius of gyration must remain doubtful.

This difficulty, as well as the equally important one of the retardation-loss, has not been recognized by previous investigators, and values have been given for mechanical efficiencies which have really been the kinetic efficiencies at full speed.

Further consideration suggested a simple and, in the author's opinion, an accurate solution of the difficulty. Given the amount of the net load to be raised during a test, let this weight be wound by the engine at a uniform slow rate of motion from the bottom to the top of the lift, keeping steam on right up to the completion of the wind, which can be done by careful handling of the engine stop-valve. The torque of the load at the drum-radius then acts as a dynamometer, eliminating all kinetic loss due to acceleration and retardation.

The value of $(F.P.)_m$ then becomes equal to $(F.P.)_g$, the friction-loss being $I.F.P.-(F.P.)_g$, and the equation for the mechanical efficiency at slow speed becomes:—

$$E=\frac{(F.P.)_g}{I.F.P.} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (53)$$

The actual mechanical loss due to friction in a steam-engine is largely dependent upon lubrication, and several authorities have stated their opinion, on the evidence of careful tests, that the friction co-efficient is practically independent of the pressure in the engine-cylinders. In the case of a winding-engine, however,

[redacted]

The same net load was used throughout the dynamic test of each individual plant, and was fixed at the average weight per run under ordinary working conditions. Every care was taken to ensure the accurate recording of the data, each tub being specially weighed and the total tare on the empty-side deducted from the total weight of full tubs. The invoice-weights of the winding-ropes were obtained, and, where possible, the actual weight of the cages and suspending gear. The weights of the pit-head pulleys were taken from the makers' lists; but, for the reasons given in Section II., no attempt was made to estimate the weights of the winding-drums. The approximate weights, as given by the colliery engineers, are, however, inserted in the tables.

The depth of the wind was determined in each instance by measuring the circumference of the drum, correcting for the diameter of the rope, and multiplying by the number of revolutions. The result in several instances was found to vary slightly from the nominal depth of the pit—a point of considerable importance in determining the actual effective work.

As several of the cylinders had been re-bored, the actual gauge-diameter was obtained for the calculation of the effective piston-area, the area of the piston and tail-rods being, of course, deducted from the full area.

Subsequent to No. 1 test, it was discovered that the weights of the cages and ropes might not be identical on either side. Hence the necessity of the procedure subsequently adopted, namely, the duplication of the slow-speed tests on both the overlap and underlap ropes, the mechanical efficiency being determined by the mean result.

IV.—Instruments Employed.

(1) *Indicator*.—The practical impossibility of accurately scaling a number of varying diagrams superposed upon a single card, rendered it absolutely necessary to employ a continuous-diagram indicator for the dynamic tests. Although four indicators for the simultaneous indicating of each cylinder would have been more expeditious, it will be noted that errors of variation were practically eliminated by retaining the same uniform net load for each trip; by keeping the boiler-pressure as constant as possible; and by ensuring that the point of shutting off steam in

the full-speed tests should be uniform, by noting that point upon the winding-indicator.

As the value of the results depended upon the accuracy of the instrument, considerable thought was given to its selection, ad-

[redacted]

The essential features of a good instrument are:—Accurate standard area of piston; minimum amount of friction of the piston-guides and pencil motion; accurate calibration of the springs; strength and lightness of the pencil motion; accuracy of the multiplication ratio and exact parallelism between the motion of the pencil point and the drum-axis. The latter detail is of particular importance in a continuous indicator, as the pencil-point must have sufficient pressure upon the paper to give a clearly-defined diagram with one line only, and hence any inequality of pressure causes more friction than in the case of an ordinary single-card diagram.

The instrument ultimately selected was a McInnes-Dobbie external-spring type indicator, fitted with half- and quarter-inch area pistons,* and with a continuous drum interchangeable with an ordinary drum for taking single diagrams. Fig. 1 is a photograph of the indicator as fitted with the continuous-drum. With one or two adjustments suggested by the author, this instrument fulfilled satisfactorily the above requirements.

The pressure-springs used were tested by dead-weights and straight-line diagrams, the maximum deviation observed being 0·9 per cent. and the mean variation 0·4 per cent. As the springs are external to the cylinder, no hot test was required, and it is probable that the above small deviation was due rather to the additional friction with a cold cylinder than to any variation in the springs themselves. The piston-area in combination with the springs was checked by a mercury column up to a pressure of 34 pounds per square inch, and found to be correct.

The reduction of the engine-stroke was effected by a reducing-wheel, except in the case of No. 5 plant, where a pendulum-lever gear was employed, being already fitted to the engine. The indicator was connected to the cylinders in the usual way by a breeches-pipe and three-way cock, except in the case of No. 5 plant, where the connection was made directly by a separate cock to each end of the cylinder.

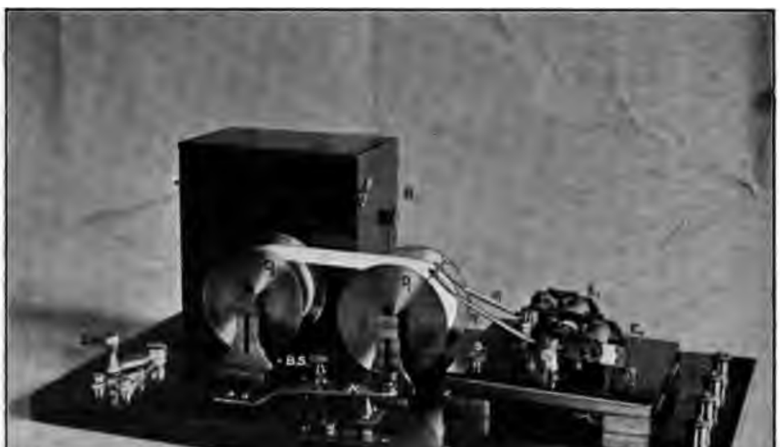
Tests were carried out on No. 2 plant by means of two indicators, previously calibrated, operating simultaneously, one attached to the cylinder direct and one attached to a three-way cock and connecting-pipes, so as to ascertain what effect, if any, the length of connecting-pipe had upon the area of the diagram. Care-

* The half-inch area piston was used throughout the experiments.

ful measurements of several pairs of cards, taken simultaneously both at slow and full speeds, revealed no measurable difference in the mean effective steam-pressure.

Each single card of the continuous diagrams was separately integrated by a planimeter, and the average steam-pressures calculated by the slide-rule.

(2) *Tachometer.*—In order to ascertain the necessary data for plotting the velocity and acceleration curves, the author designed a form of tachometer, or speed-recorder, to give a complete record of each wind and the time of each revolution to one-hundredth of a second.



[redacted]

The electro-magnet, E_1, is connected through a battery or other suitable source of current to an electric contact, fitted on the indicator (not shown in fig. 1), which closes the circuit, and thus actuates the pencil, P_1, at each revolution of the engine. The switch, SW, serves to short-circuit this armature at the commencement and end of the wind, and may be operated either by hand or by an electric contact fixed on the winding depth-indicator. The pencil and armature, P_2, is actuated through suitable connections by means of the contact-key, K, or alternatively by means of an electric clock, and records equal intervals of time on the moving strip of paper.

To obtain a record of the winding during the steam trials of No. 2 plant, the speed of travel of the drum, D_2, and the paper-strip, was reduced by the addition of an escapement to the clockwork; the magnet, E_1, was connected to a contact on the depth-indicator, thus giving the total time of each trip, and the magnet, E_2, to a contact on the handle of the steam stop-valve, giving the exact time under steam. The same arrangement was adopted for the steam-test of No. 5 plant, except that the pencil, P_2, was operated by hand, as the steam-valve was controlled by a hand-wheel instead of a regulating-handle.

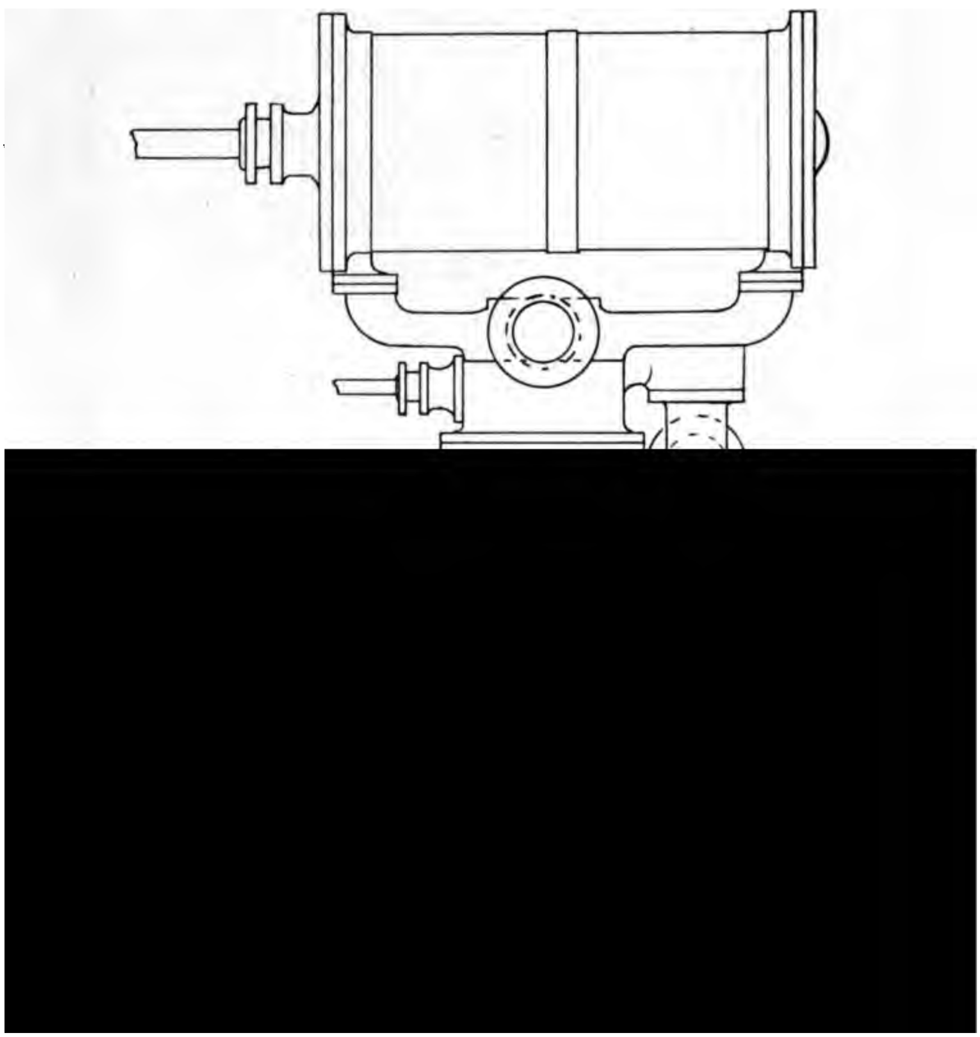
As will be seen from the sample records (figs. 24, 27, and 30, plates xxiv. and xxv.), and the speed diagrams for each plant, this instrument furnished very interesting information, enabling the rope-speed and piston-speed to be calculated and the acceleration curves to be plotted with an exactness unattainable by other means.

V.—Description of the Plants Tested.

No. 1 Plant.—The engines of this plant were built by Messrs. Thornewill & Warham in 1882, and have two horizontal cylinders of 42 inches nominal diameter by 6 feet stroke, with valve-gear of the double-beat Cornish type, actuated by the usual link-motion. The winding-drum is cylindrical, 19·3 feet in diameter, and has a built-up rim carried on channel-steel arms from a cast-steel boss keyed to the shaft. The engines are provided with both a steam and foot-brake, operating two brake-straps on the outer rings of the drum. The winding-ropes, of plough-steel, carry two-decked cages; and the plant winds four tubs

per trip from a depth of 1,615 feet, the boiler-pressure being from 60 to 65 pounds per square inch. Detailed dimensions will be found in Table I., Appendix III.

No. 2 Plant.—The engines of this plant were built by Messrs. Pigott & Farrar, Barnsley, in 1864, and have two horizontal cylinders of 24 inches nominal diameter by 4 feet stroke, with ordinary slide-valves and link-motion, the valves being relieved from full steam-pressure by a back cover adjusted by set-screws. The valve-chests are of an old-fashioned construction (fig. 3), being a separate casting with long port-passages bolted to the cylinder proper, this arrangement resulting in excessive clearance loss.



horizontal cylinders of 40 inches nominal diameter by 5·5 feet stroke, with valve-gear of the double-beat Cornish type, actuated by Allan link-motion. The winding-drum is cylindrical, 19·65 feet in diameter, and is of cast-iron, the arms of the two outer rings being of T-section and those of the middle ring of oval section, with a single brake-strap on the middle ring operated by foot-gear only. The winding-ropes, of plough-steel, carry three-decked cages, and the plant winds six tubs per trip from a depth of 1,138 feet, the boiler-pressure being 50 pounds per square inch. Detailed dimensions will be found in Table V., Appendix III.

No. 4 Plant.—The engines of this plant were built by Messrs. Yeadon & Company, Leeds, about the year 1875, and have two horizontal cylinders of 24 inches nominal diameter by 4·5 feet stroke, with ordinary slide-valves and link-motion, the valves being relieved from full-steam pressure by means of a back cover. This plant is provided with a Kœpe winding-pulley, 20·3 feet in diameter, consisting of an additional casting bolted to the middle ring of the original drum, 12 feet in diameter, which is still retained. This adaptation gives no reduction in the total weight consequent on the use of the Kœpe winding-pulley; but the plant is installed at an upcast shaft, and is only used for raising and lowering men and material. The bottom of the rope-groove is packed with hemp, and the ring-casting on either side of the groove serves as a brake-ring for the brake-strap, which is operated by foot-gear. The winding-ropes, of plough-steel, carry single-deck cages, and the plant is capable of winding two tubs per trip from a depth of 1,621 feet, the boiler-pressure being 60 pounds per square inch. The balance-rope is of iron, and, as will be noted, is 0·5 pound per foot heavier than the winding-rope, the result being a reduction of 810 pounds in the net load at the lift and an increase of that amount at the end of the wind. Detailed dimensions will be found in Table VII., Appendix III.

No. 5 Plant.—The engines of this plant were built by Messrs. John Slee & Company, Earlstown, Lancashire, in 1901, and have two horizontal cylinders of 36 inches nominal diameter by 6 feet stroke, with double-beat Cornish valves actuated by link-motion and controlled by a Melling steam reversing-gear. Automatic ex-

pansion trip-gear, operated by a governor, is also provided, but is not yet in operation. The winding-drum is cylindrical, 17·84 feet in diameter, and is of cast-iron of fairly heavy construction, having three rings with H-section arms. The engines are provided with both a steam and a foot-brake, operating two brake-straps on the outer rings of the drum. The winding-ropes, of plough-steel, carry two-decked cages, and the plant winds six tubs per trip from a depth of 1,659 feet, the boiler-pressure being from 100 to 120 pounds per square inch. Steam is supplied from a separate range of six Lancashire boilers, 30 feet in length by 8 feet diameter, five only being under steam at the date of the test. Detailed dimensions will be found in Table IX., Appendix III.

No. 6 Plant.—The engines of this plant were built by the Worsley Mesnes Ironworks Company, Wigan, in 1905, and have two horizontal cylinders 30 inches in diameter by 5 feet stroke, with slide-valves and link-motion controlled by Melling steam reversing-gear. Melling's patent automatic expansion valve-gear is also provided, being operated in conjunction with the main slide-valves by a third eccentric and connecting-link, the position of the latter being varied by a governor driven from the engine-shaft. The winding-drum is cylindrical, 15·78 feet in diameter, and is of cast-iron of light construction, having two rings of T-section arms, the width being limited to 5·3 feet, as the on-going rope laps in the grooves of the off-going rope. [redacted]

the formulæ in Section II., references to the formulæ and equations used being given in each table.

The mechanical efficiency having been determined by the test at slow speed, the equivalent friction-loss is deducted from the indicated foot-pounds for the full-speed wind, the difference being the total mechanical energy; from this quantity is deducted the effective work performed up to the point of shutting off steam, the remainder being the total kinetic energy. The weights of the ropes, cages, tubs, coal, and head-gear pulleys being fairly accurately known, the value of the component $(F.P.)a_1$ can be calculated by the formulæ given in equation (3), and the kinetic energy of the winding-drum then apportioned by difference.

The remaining net work for the completion of the wind being then deducted from the total kinetic energy determines the retardation loss, and to this must be added the amount of the friction coefficient to give the total kinetic loss for the wind. Attention will be called to the wide variation in the amount of this loss under different conditions of winding.

Figs. 33 to 44 (plates xxvi. to xxxi.) are diagrams plotted to scale from the calculations for each test, and exhibit graphically the numerical values set out in the Tables. They show clearly the relation between the indicated force, the total mechanical force, and the net load; and between the indicated, mechanical, and effective horsepowers at any period of the wind. The area beneath the zero line in the power-diagrams represents to scale the amount of the retardation loss as determined by equations (41) and (42). The size of this area relative to the total area enclosed by the line of "indicated tangential force" presents graphically the influence of the principal factor in the comparative kinetic efficiency of each plant.

The tangential-speed curves are plotted, in each case, from the mean of the tachometer-records, and the acceleration and retardation curves are plotted from the formula $\left(a=\frac{dv}{dt}\right)$, the variation in v for each revolution being scaled from the velocity curve and divided by the time of each revolution, as given by the tachometer scale.

The records of the tests contained in Appendix III. furnish the information from which have been compiled the comparative

[redacted] A.—COMPARATIVE RESULTS OF THE DYNAMIC TESTS.

	WINDING-PLANTS.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
[redacted] ...	1,615	677·4	1,138	1,621	1,659	1024·6
[redacted] ..	5,200	3,472	9,814	3,060	7,076	4,783
[redacted] et in ...	16·27	21·93	26·92	15·68	11·77	13·75
[redacted] ...	44·25	26·40	45·00	68·00	48·30	34·80
[redacted] ...	23·92	18·07	37·00	63·50	27·00	20·40
[redacted] ...	36·8	25·6	25·3	23·8	34·3	29·4
[redacted] ...	69·2	44·0	41·3	47·4	65·8	46·7
[redacted] ...	7·13	7·04	4·18	4·65	7·32	5·87
[redacted] total ...	69·8	72·4	87·3	76·3	64·7	72·7
[redacted] ...	8,398,000	2,351,933	11,168,332	4,960,260	11,739,084	4,900,662
[redacted] e, in ...	13,212,108	3,133,790	13,373,043	6,065,503	19,517,930	7,013,911
[redacted] ...	91·7	87·75	90·2	88·45	89·11	92·17
[redacted] ...	63·6	75·05	83·5	81·78	60·15	69·87
[redacted] ...	28·1	12·70	6·7	6·67	28·96	22·30
[redacted] ...	30·7	14·46	7·4	7·54	32·50	24·20
[redacted] ...	1,075	425	840	376	1,620	992
[redacted] ...	1,004	315	657	173	1,314	625
[redacted] ...	920	277	593	153	1,171	576
[redacted] ...	345	215	451	132	442	256

data in Table A, exhibiting the principal points of relative importance, which will be further considered in detail.

(a) *Indicator Diagrams.*—It was the writer's intention to reproduce a complete set of continuous indicator diagrams for both the slow and full-speed tests on each plant, but the desirability of keeping the number of plates within reasonable limits has necessitated their restriction to one example from each test. Reference to several important details in the valve-setting will consequently have to be omitted, but the following points are worthy of note:—

The engines of No. 1 plant are troubled with wet steam, and the resulting accumulation of water in the connecting-pipes to the indicator had an objectionable effect upon the diagrams (fig. 6, plate xxiii.). It will be seen that the area of valve-opening or of the steam pipe is insufficient for the high piston-speed (over 800 feet per minute), resulting in excessive fall of pressure and wire-drawing. The steam valves of the engine are only 10 inches in diameter, which means that, in order to maintain the initial pressure, the steam velocity through the valves at the maximum piston-speed would require to be about 13,000 feet per minute.

The diagrams of No. 2 plant (fig. 8, plate xxiii.) show a good steam-line, but the back-pressure might be reduced by an earlier exhaust.

The diagrams of No. 3 plant (fig. 10, plate xxiii.) show defective valve-setting, the steam admission and exhaust both being late.

The diagrams of No. 4 plant (fig. 12, plate xxiii.) show good steam distribution for slide valve engines running without expansion.

The diagrams of No. 5 plant show very bad valve-setting, fig. 14 (plate xxiii.) being the best diagram obtained from either cylinder. The remaining diagrams exhibited very late steam admission in addition to the late exhaust. It will be noted that the back-pressure is excessive, partly in consequence of both engines exhausting into one exhaust-pipe. The high piston-speed also has an influence on the amount of back-pressure and on the falling steam line.

The diagrams of No. 6 plant are of exceptional interest, and are reproduced in figs. 16 to 23 (plate xxiv.). They differ very

essentially from all the preceding diagrams, in consequence of the action of the automatic expansion-gear; its influence upon the maintenance of the initial pressure, the reduction of the back-pressure, and the general steam-consumption, is evident by inspection, although the steam admission by the main valve might be slightly improved as evidenced in figs. 20 and 23 (plate xxiv.). The smoothness of running of these engines and the absence of noise with this type of expansion-gear were satisfactory features.

A comparison of these continuous diagrams for each plant will show very clearly the relative number of compression-strokes during retardation; but, in the case of No. 4 plant, it will be noticed that steam is shut off at the nineteenth revolution for about two-and-a-half strokes, and then readmitted to complete the wind.

All the tests were made with the engines in their usual working condition, and the diagrams clearly indicate the difficulty of correct valve-setting without the use of an indicator, and the utility of that instrument in revealing unsuspected faults and consequent loss in the distribution of steam. Attention may be called to the fact that the engines fitted with slide-valves showed better steam distribution than those fitted with drop-valves, and the writer would suggest this as a point upon which further discussion and the experience of other members would be of interest.

[redacted]

The mean of the values in Table A gives an average mechanical efficiency for the complete winding-plants of 89·89 per cent., or excluding No. 1, 89·53 per cent. In view of the care with which the experiments were made, and the precautions taken to ensure accuracy, the writer has confidence in recording this as an authoritative result.

No opportunity presented itself of obtaining the friction coefficient for the guides and pit-head pulleys, but it is evident that too high a value has been previously assigned for this; in the writer's opinion it does not exceed 1 to 1·5 per cent., depending upon the total load.

Subsequent to No. 3 test, a balancing-test was carried out on the remaining plants, to ascertain the variation in the equilibrium, and with the view of bringing the calculations on the two sides into the closest possible agreement. It will be noted that after applying this correction to the net load in the case of Nos. 4, 5, and 6 plants, the results of the tests at slow-speed on the underlap and overlap ropes are in remarkably close agreement, the differences being 0·30, 0·37, and 0·43 per cent. respectively (Tables VIII., X., and XII., Appendix III.).

The balance test of No. 4 plant afforded very interesting data. Upon scaling up the indicator diagrams of the slow-speed tests, the writer found a considerable discrepancy between the mean steam-pressure on the two sides, amounting to 5·33 pounds or 17·51 per cent. (Table VIII., Appendix III.). On a net load of 30 hundredweights, this would represent a net difference in weight on the two sides of 294 pounds. Upon investigating the matter at the colliery, he found that the left-hand cage was a new one, and the right-hand cage an old one. As the balance-rope is 0·5 pound per foot heavier than the winding-rope, there is an overbalance of 810 pounds when one cage is at the top of the shaft; consequently, with the brake off and the steam-valve closed, the engines will creep back until the two sides are in equilibrium.

The light cage was then loaded up until the distance that the engines would travel either way was as nearly as possible identical; the total weight to restore the balance was found to be 300 pounds, a difference of 6 pounds from that theoretically computed.

When the balance of the two cages had been restored, mea-

surements were taken of the distance that the engines would creep before coming to rest, and it will be evident that this position of rest would be determined by the point at which the retarding moment due to friction would equal the turning moment due to the remaining overbalance at that point. The mean of several trials gave 10·5 revolutions or 672 feet. As the total length of the wind is 1,621 feet, we have for the value of the retarding force due to friction:

$$F_f = 1{,}621 - 0{\cdot}5(672 \times 2) = 138 \text{ pounds.}$$

This means that a force of 138 pounds at the drum-radius would equal the friction resistance of this particular plant when unloaded and free from steam pressure; at the drum radius of 10·18 feet, it equals a torque of 1,405 pound-feet, and on a net load of 30 hundredweights would amount to only 4·1 per cent. This may be regarded as a confirmation of the figures obtained for the mechanical efficiency.

Similar balance-tests were made on Nos. 5 and 6 plants, the difference in the point of equilibrium of No. 5 being 0·75 of a revolution, or 42·4 feet of rope, which equals 228 pounds. In the case of No. 6 plant, the difference in the point of equilibrium was found to be 1⅓ revolutions or 66·6 feet of rope, which equals 245 pounds. These corrections have been applied to the respective calculations.

(*c*) *Kinetic Efficiency and Retardation Loss.*—Attention was [redacted]

and it will also be clearly established that tests of steam-consumption, based solely upon the net effective work, cannot be accepted as conclusive evidence of the merits or otherwise of any particular winding-engine or method of steam distribution.

The factors accounting for this loss of energy have been fully dealt with in Section II., but their influence in each case will admit of further examination. It will be noticed from Table A that the lower efficiencies were obtained with the maximum winding-speeds and the highest efficiency with the lowest speed, coupled with the maximum ratio between the net effective load and the total weight to be set in motion (No. 3 plant); thus confirming the theoretical deduction that, for the same output, it is higher economy to wind a heavy load at a lower speed than a lighter load at a high speed.

The ratio of the total weight of the moving masses to the net load has an important bearing upon the limitation of the speed at which the maximum efficiency can be obtained, and in this connection the design of the winding-drum is of considerable importance.

The economic recuperation of the kinetic energy will be considered in its relation to design in Section VIII., but it may be mentioned here that this is one of the advantages claimed by the advocates of electric winding, or, at any rate, for the Ilgner system. The very high rheostatic losses in acceleration and retardation in other systems would probably discount any advantages in this direction; but it is claimed for the Ilgner system that whatever the speed of winding and however the energy of momentum may vary, due to the handling of the motor, the whole of this energy, less the conversion-loss, is returned to the fly-wheel converter during retardation. But against this has to be set the lower total mechanical and conversion efficiency; and, so far as the writer is aware, the ratio of the mechanical energy of the winder to the indicated energy of the generator falls very far below the 88 or 90 per cent. mechanical efficiency of the steam winder.

As already pointed out, tests based solely on the net effective work are inconclusive; the only available test of efficiency which the writer has discovered is that given by Mr. F. Hird of the electric winder on the König-Wilhelm II. shaft at Fried-

richshall.* The ratio of net effective work to total electrical energy is there given as 44·5 per cent., and, allowing 90 per cent. electrical and mechanical efficiency of the generator, this gives 40 per cent. efficiency from the indicated to net useful work. It is to be regretted that data are not available as to the distribution of the energy, but it will be evident either that the over-all mechanical and conversion efficiency is very low, or that the whole of the kinetic energy is by no means utilized, and that there is considerable kinetic loss.

While maintaining an open mind as to the advantages of electric winding where the plant is part of a large scheme of general power distribution, the writer would put the following proposition to the advocates of electric winding for isolated plants:—Provided that a high-class steam winding-plant, working expansively or compound can be designed and run with a total kinetic efficiency of 85 per cent. for a capital expenditure of £2,500 per 100 tons per hour; are they prepared to bring forward accredited tests showing such economy as would justify the expenditure of three times that amount on an electric plant?

(*d*) *The Kœpe Winding System.*—The power and velocity diagrams for this test (figs. 39 and 40, plate xxix.) exhibit several interesting features, this being the only instance where a constant speed was maintained for any portion of the wind. The mean velocity for the wind is the lowest recorded, this being due to the slower rate of retardation and the low velocity for the last

[redacted]

sive the test should be made with all other engines shut down, as estimates and allowances for the consumption of other plant are vague and unsatisfactory. As it is the exception to find a winding-engine supplied exclusively by separate boilers, this condition usually excludes the carrying out of the test under ordinary working conditions. This was the case with all the plants tested excepting No. 5; but special arrangements were made in the case of No. 2 plant, mainly for the purpose of ascertaining whether the steam-consumption on the effective work would vary in proportion to the kinetic efficiency.

No. 2 Winding-plant.—These engines, in common with the other colliery plant, are supplied with steam from a battery of five egg-ended boilers and two Lancashire Galloway boilers. For the purpose of this test, which was made after working hours, the stop-valve between the Lancashire boilers, supplying steam to the fan and hauling-engines, etc., and the remaining boilers, was closed, and all connections to the five boilers shut down, with the exception of 210 feet of 5-inch steam range to the No. 2 pit, which it was not considered advisable to close, owing to the risk of the joints giving out. The results recorded in Table XIX., Appendix IV. include the condensation in this range, but with this exception every other source of loss was eliminated.

The net load was fixed at the same amount as for the dynamic test, namely, 31 hundredweights, and the engines were kept winding with the same load, the precaution being taken to run back with the stop-valve closed to avoid the use of steam in checking. Single-card indicator-diagrams were taken every five minutes, samples of which are illustrated in figs. 25 to 29 (plate xxv.), the mean scalings of the total number being taken for calculation.

The steam-consumption was obtained from the volume of feed-water by duplicate measurements, the displacement of the water-level in each boiler during the test was carefully noted, and as the exact internal dimensions of each boiler were known, the total volume was easily calculated. No feed-water was sent into the boilers during the period of testing, but only during the changing of the indicator; at the conclusion of the test, the quantity required to fill the boilers to the original level was

obtained by measuring the displacement in the feed-water tank. The quantities obtained by the two methods of measurement agreed within 1 per cent.

The test on November 7th, 1907, was carried out whilst winding at full speed, and shutting off steam at 12·5 revolutions, the control being practically identical with that of the dynamic test of May 27th, 1907, except that the mean steam-pressure was 0·66 pound higher, resulting in a slightly less time for the wind and a slightly greater indicated horsepower.

The test of November 11th, was carried out with recuperative control, that is, shutting off steam as nearly as possible at such a point that the accumulated energy would suffice to complete the wind. This was found to be at 11 revolutions, resulting in the run being made in 28·1 instead of in 26 seconds.

The comparative results are important and instructive; it will be noticed that the kinetic efficiency was increased from 73·6 per cent. to 83·4 per cent., being only 4·35 per cent. below the figure for the mechanical efficiency. The total steam used was practically the same in both tests, but 85 runs were made on November 11th, against 75 runs on November 7th, this being entirely due to a little more smartness on the part of the engineman in reversing and running back. The resulting steam-consumption, while being practically identical when calculated on the indicated and mechanical horsepowers, varied from 120·3 pounds to 105·4 pounds per effective horsepower-hour, the net

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The steam-consumption of 88·3 pounds per indicated horse-power is excessive, but not exceptional at the pressure. Only about 50 per cent. is accounted for by the indicator-diagrams, the remainder being lost in condensation and clearance; the latter (as mentioned in the description of the plant) being abnormal, owing to the construction of the valve-chests. The length of the wind and ratio of the time under steam to the total duration of the test have also probably influenced the result which might be somewhat improved upon in normal working.

No. 5 Winding-plant.—As already mentioned, this plant is supplied with steam from a separate range of six Lancashire boilers, 30 feet by 8 feet, five of which were under steam at the date of the test, which was carried out during the winding shift, and as nearly as possible in conformity with the conditions laid down in Appendix II.

All steam-supply other than to the winding engines was eliminated, with the exception of the steam required to run a small pump for one hour during the period of the test. The details of this pump and its estimated steam-consumption are included in Table XX., Appendix IV. The quantity is, however, so small in comparison with the total consumption, that the accuracy of the estimation will not materially affect the result.

The total feed-water was obtained by measuring the capacity of the feed-tank between fixed gauge-marks, the time of emptying and filling being noted by the observer in charge. The method of indicating and recording the time of winding was similar to that employed in the test of No. 2 plant already described, indicator-diagrams being taken at intervals of ten minutes.

As already noted in the summary of the dynamic tests, the kinetic efficiency of this plant under the conditions of winding at the date of the test was only 60·15 per cent., being due partly to the high speed attained, together with the low ratio of net load to total weight. As will be seen from the load line in fig. 41 (plate xxx.), the weight of the winding-rope actually exceeds the net weight of coal, resulting in a negative load at the end of the wind and necessitating excessive braking and counter-pressure in the cylinders during retardation. The low kinetic

efficiency results in a very considerable divergence between the steam-consumption per indicated-horsepower-hour and per effective-horsepower-hour.

The defective valve-setting also has an effect upon the steam-consumption, 61 per cent. of the steam used being accounted for by the indicator diagrams; in fact the design and running of this plant cannot be considered satisfactory for a modern installation. Its capacity is, of course, far above the present output, and the writer hopes to be in a position at a future date to communicate the results of a further test upon this plant with the expansion-gear in operation and winding a heavier net load.

The results of these tests are not recorded as presenting anything approaching good steam practice, but they serve to illustrate the points upon which economy depends and also to demonstrate the correct basis of comparison. It will be noted that on the effective horsepower, No. 2 winding engine would have been considered the more economical engine, whereas the reverse is actually the case.

VIII.—The Design of Winding-plant.

(*a*) *Theory*.—The design of a winding-plant to perform the required work with the maximum kinetic efficiency necessitates a somewhat complicated mathematical analysis, and the evolution of the fundamental formulæ from an entirely new basis.

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total time for the trip, together with the total weight to be set in motion, determine the point of shutting off steam, such that the maximum amount of the kinetic energy may be utilized in effective work; determine also the initial acceleration and the maximum velocity required to complete the wind in the given time.

It has been assumed, in all previous empirical formulæ in connection with winding problems, that the acceleration is uniform; but it will be evident, from an inspection of the diagrams accompanying this paper, that this is rather the exception than the rule. It can only be possible in the case of a uniform load where the initial mean effective pressure of steam is practically maintained during steam-admission; or, in the case of a varying load, where the effective steam-pressure varies in proportion thereto. In the case of an electric winder, the acceleration would only be uniform provided the current were so regulated as to give a torque proportional to the load.

The precise form of the acceleration curve may not in every instance lend itself to mathematical evaluation, but generally it approximates very closely either to a straight line, uniformly decreasing in relation to time, or to some form of parabolic curve on a time base. The form of the retardation-curve varies very erratically in the several cases recorded, consequent on the varying control adopted; but under the conditions now to be considered, namely, recuperation of the kinetic energy during retardation, the rate of retardation will either be uniform or will uniformly decrease in relation to distance.

Mr. A. Adams, of Smethwick Technical School, has kindly undertaken for the writer a comprehensive analysis of the relation between velocity, distance, and time, for several types of varying acceleration, the results of which are tabulated in Appendix I., and will be found of very useful application in winding calculations.

As therein explained, the time for acceleration and retardation may be expressed in terms of the distance and velocity, the value of the co-efficients β and γ varying with the type of acceleration and retardation.

Employing the same notation as in Section II. and in Appendix I., a general formula may be evolved to determine the distance required for retardation under the conditions of the

problem previously stated, namely:—Given the time of the wind and the depth with the net load and the total mass.

Assuming first that the period of acceleration is co-terminous with the time under steam, that is, that λ_a equals λ_t and t_a equals t, we have:—

$$T = t_a + t_r = \beta.\frac{\lambda_a}{v} + \gamma\cdot\frac{\lambda_r}{v} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (54)$$

$$= \frac{\beta(\lambda - \lambda_r) + \gamma.\lambda_r}{v} \quad . \quad . \quad . \quad . \quad . \qquad (55)$$

Therefore, $$v = \frac{\beta.\lambda + (\gamma-\beta)\lambda_r}{T} \quad . \quad . \quad . \quad . \quad . \quad . \qquad (56)$$

Under the conditions of recuperative control, the kinetic energy will equal the mean retarding force, including friction, multiplied by the distance for retardation. Let W_r equal the equivalent total weight of the moving masses at the drum radius:—

Then, $$\lambda_r \times F_{rm} = \frac{W_r . v^2}{2g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (57)$$

Substituting the value of v from equation (56) gives:—

$$\frac{\lambda_r . F_{rm}.2g.T^2}{W_r} = (\beta.\lambda + (\gamma-\beta).\lambda_r)^2 \quad . \quad . \quad . \quad . \quad . \quad . \qquad (58)$$

From which,

$$\lambda_r^2 - \lambda_r.\frac{F_{rm}.2g.T^2/W_r - 2\beta(\gamma-\beta).\lambda}{(\gamma-\beta)^2} = -\left(\frac{\beta\cdot\lambda}{\gamma-\beta}\right)^2 \quad . \qquad (59)$$

or, $$\lambda_r^2 - \lambda_r.\left(\frac{F_{rm}.2g.T^2}{W_r(\gamma-\beta)^2} - \frac{2\beta}{\gamma-\beta}.\lambda\right) = -\left(\frac{\beta\cdot\lambda}{\gamma-\beta}\right)^2 \quad . \qquad (60)$$

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$$T = t_a + t_c + t_r = \frac{\beta\lambda_a}{v} + \frac{\lambda_c}{v} + \frac{\gamma.\lambda_r}{v} \qquad (63)$$

$$= \frac{\beta(\lambda - \lambda_c - \lambda_r) + \lambda_c + \gamma.\lambda_r}{v} \qquad (64)$$

Therefore, $$v = \frac{\beta.(\lambda - \lambda_c + \lambda_c/\beta) + (\gamma - \beta)\lambda_r}{T} \qquad (65)$$

or, $$v = \frac{\beta.\lambda + (\gamma - \beta)\lambda_r}{T - (1 - \beta)t_c} \qquad (66)$$

Substituting these values of v in equation (57) gives:—

$$\lambda_r = \pm\sqrt{\left[\frac{F_{rm}.g.T^2}{W_r.(\gamma-\beta)^2} - \frac{\beta}{\gamma-\beta}(\lambda-\lambda_c+\lambda_c/\beta)\right]^2 - \left(\frac{\beta}{\gamma-\beta}\right)^2.(\lambda-\lambda_c+\lambda_c/\beta)^2}$$
$$+\frac{F_{rm}.g.T^2}{(W_r.(\gamma-\beta)^2} - \frac{\beta}{\gamma-\beta}.(\lambda-\lambda_c+\lambda_c/\beta) \qquad (67)$$

or,

$$\lambda_r = \pm\sqrt{\left(\frac{F_{rm}.g(T-(1-\beta)t_c)^2}{W_r.(\gamma-\beta)^2} - \frac{\beta}{\gamma-\beta}.\lambda\right)^2 - \left(\frac{\beta.\lambda}{\gamma-\beta}\right)^2}$$
$$+\frac{F_{rm}.g(T-(1-\beta)t_c)^2}{W_r.(\gamma-\beta)^2} - \frac{\beta}{\gamma-\beta}.\lambda \qquad (68)$$

And in the special instance where β equals γ,

$$\lambda_r = \frac{W_r.\beta^2.(\lambda-\lambda_c+\lambda_c/\beta)^2.}{F_{rm}.2g.T^2} \qquad (69)$$

or, $$\lambda_r = \frac{W_r.\beta^2.\lambda^2}{F_{rm}.2g.(T-(1-\beta)t_c)^2} \qquad (70)$$

It will be noted that the value of the retarding-force, F_{rm}, includes, in addition to friction, the tangential value of the cylinder-resistance, which, from an examination of the indicator diagrams and actual experiment may be estimated at 3 to 7 pounds per square inch of piston area. The remaining component of F_{rm} will vary with the net load, and, unless a balance-rope is used, will equal $L - w_r.\lambda_t$. Thus, in the case of a varying load, the value of the mean retarding force is partially dependent upon the value of λ_r, which has to be determined; but, as the inclusion of this variable would have rendered the equations unwieldy in application, it has been omitted, leaving the value of F_{rm} to be determined by a preliminary approximate calculation.

The value of the distance required for recuperative retardation determines the ultimate velocity, v, with the distance and number of revolutions under steam, from which the total mechanical energy may be obtained by equations 2 to 6 (Section II.). Equating with the indicated energy in the cylinders, we have:—

$$(F.P.)_m = A \times P \times 2S \times N \times n_t \times E \quad . \quad . \quad . \quad (71)$$

$$= D^2 \times \cdot 7854 \times P \times R.D/6 \times N \times n_t \times E \quad . \quad (72)$$

From which $$D = \sqrt[3]{\frac{(F.P.)_m}{0 \cdot 1309 \times P \times R \times N \times n_t \times E}} \quad . \quad . \quad (73)$$

If L_1 equals the unbalanced load at the lift and L_m equals the mean unbalanced load for n_t revolutions, then the ratio of the mean effective pressure, P, for n_t revolutions to the initial effective pressure P_1 is given by the equation:—

$$P = \frac{L_m + F_m}{L_1 + F_1} . P_1 \quad . \quad . \quad . \quad . \quad . \quad . \quad (74)$$

F_m being obtained from the equation in Appendix II., giving its value in terms of F_1 for that particular acceleration-curve and F_1 being equal to $a_1 \times W_r / g$.

We have, then, as an alternative evaluation for the size of engine required:—

$$(L_1 + a_1 \cdot W_r / g) . 2\pi . r = A \times P_1 \times N \times 2S \times E \quad . \quad . \quad . \quad . \quad (75)$$

$$= D^2 \times \cdot 7854 \times P_1 \times N \times R.D/6 \times E \quad . \quad . \quad (76)$$

And, therefore, $$D = \sqrt[3]{\frac{(L_1 + a_1 . W_r/g).48.r}{P_1 \times N \times R \times E}} \quad . \quad . \quad . \quad . \quad (77)$$

A further important application of the formulæ is the determination of the time in which a given engine will raise a given load with a given steam-pressure and rate of acceleration; or, of the variation in the time of the wind which will result from an alteration in the net load, or in the range of expansion and consequent modification of the acceleration curve.

[redacted]

wind; then, in the absence of a balance-rope, the mean unbalanced load during retardation equals $L_2 + w_f \cdot \lambda_r$, and therefore:—

$$F_{rm} = \frac{F_c + L_2 + w_f \cdot \lambda_r)}{E} \quad . \quad . \quad . \quad . \quad . \quad (81)$$

And from equation (79):—

$$\lambda_r = \frac{F_m . E(\lambda - \lambda_r)}{F_c + L_2 + w_f . \lambda_r} \quad . \quad . \quad . \quad . \quad . \quad (82)$$

From which,

$$\lambda_r^2 + \lambda_r \frac{F_c + L_2 + F_m . E}{w_f} = \frac{\lambda . F_m . E}{w_f} \quad . \quad . \quad (83)$$

And, therefore,

$$\lambda_r = \pm \sqrt{\frac{\lambda \cdot F_m \cdot E}{w_f} + \left(\frac{F_c + L_2 + F_m \cdot E}{2w_f}\right)^2} - \frac{F_c + L_2 + F_m \cdot E}{2w_f} \quad (84)$$

And if a period of constant velocity is included:—

$$\lambda_r = \pm \sqrt{\frac{(\lambda - \lambda_c) \cdot F_m \cdot E}{w_f} + \left(\frac{F_c + L_2 + F_m \cdot E}{2w_f}\right)^2} - \frac{F_c + L_2 + F_m \cdot E}{2w_f} \quad (85)$$

The value of λ_r, as before, determines the maximum velocity, v, which gives the value of t_a and t_r, and hence the total time of the wind.

It has been already demonstrated in Section II. that the maximum kinetic efficiency involves a minimum value of λ_r, and it will now be evident that, for a given net load, this is obtained with that particular form of acceleration-curve which gives the minimum necessary velocity to cover the distance in the required time. Further, it may be stated, as a general proposition, that for the same total time, the longer the period of the wind at constant velocity, the greater is the kinetic efficiency, but the higher the initial acceleration required.

The desirability of keeping the initial acceleration within reasonable limits here comes in as a limiting condition, in consequence of the increased tension thereby set up in the winding-rope. Table B gives the value of the increased tension and reduced factor of safety for varying rates of acceleration.

It must not be overlooked that, in the case of a deep wind with a low ratio of effective load to the total weight suspended, a high rate of retardation may possibly result in the tension in the descending rope exceeding the tension in the ascending rope at the lift, particularly if the retarding force is intermittent in its operation.

TABLE B.—COMPARATIVE TENSION IN THE WINDING-ROPE, WITH CORRESPONDING FACTORS OF SAFETY FOR VARYING RATES OF ACCELERATION.

Static Load :—Tension = 1
Factor of Safety = 10

Acceleration. Feet per Second per Second.	Tension.	Factor of Safety.	Acceleration. Feet per Second per Second.	Tension.	Factor of Safety.
0·0	1·000	10·00	—	—	—
0·5	1·015	9·85	8·0	1·248	8·00
1·0	1·031	9·70	8·5	1·264	7·90
1·5	1·046	9·55	9·0	1·280	7·81
2·0	1·062	9·42	9·5	1·295	7·72
2·5	1·077	9·28	10·0	1·311	7·63
3·0	1·093	9·14	10·5	1·326	7·54
3·5	1·108	9·02	11·0	1·342	7·45
4·0	1·124	8·89	11·5	1·358	7·37
4·5	1·140	8·77	12·0	1·373	7·28
5·0	1·155	8·66	12·5	1·389	7·20
5·5	1·171	8·54	13·0	1·405	7·12
6·0	1·186	8·43	13·5	1·420	7·04
6·5	1·201	8·32	14·0	1·436	6·97
7·0	1·217	8·21	14·5	1·451	6·89
7·5	1·232	8·11	15·0	1·467	6·82

(*b*) *Application.*—The utility and application of the above formulæ may be illustrated by examining the conditions under which the kinetic efficiency of the plants tested might be improved. Taking, for example, No. 1 winding-plant, we see that the kinetic efficiency is 63·6 per cent., with a loss of energy, so far as useful effect is concerned, of 30·7 per cent.

Assuming that the present ratio of net load to total mass were maintained, what economy would result from recuperative con-

[redacted]

unbalanced load during retardation at 3,268 pounds, and a mechanical efficiency of 90 per cent., F_{rm} will equal in round numbers 6,620 pounds.

The value of the total kinetic energy from Table XIII. equals 5,181,069 foot-pounds, which, at a velocity of 69·2 feet per second, equals an equivalent weight at the drum radius of 69,700 pounds.

Therefore, $$\frac{4 \cdot F_{rm} \cdot g \cdot T^2}{W_r} - 3\lambda = 19{,}108.$$

And $$\lambda_r = \pm\sqrt{(19{,}108)^2 - (4{,}845)^2} + 19{,}108 = 625 \text{ feet}.$$

From equation (56):—

$$v = \frac{(3 \times 1{,}615) + 625}{2 \times 44{\cdot}25} = 61{\cdot}8 \text{ feet per second}.$$

The length of the wind during acceleration, that is, during steam-admission, will equal (1,615 – 625) 990 feet, and by equation (2):—

$$(F.P.)g_t = (5{,}200 + 625 \times 1{\cdot}95) \times 990 = 6{,}353{,}820 \text{ foot-pounds}.$$

And the kinetic energy will equal:—

$$(F.P.)a = \frac{69{,}700 \times 61{\cdot}8^2}{64{\cdot}4} = 4{,}133{,}544 \text{ foot pounds}.$$

Therefore, the total mechanical energy $(F.P.)_m$ equals 10,487,364 foot-pounds; and

$$I.F.P. = \frac{10{,}487{,}364}{0{\cdot}9} = 11{,}652{,}627 \text{ foot-pounds}.$$

As the present indicated energy per wind equals 13,212,108 foot-pounds, this variation of control represents an economy of 11·8 per cent., the resulting kinetic efficiency being 72·1 per cent.

Considerably greater economy than this might be effected by winding six tubs per trip instead of four, that is, by increasing the net load 50 per cent. The present rate of winding, after allowing time for banking, is, approximately, one run per minute, which, with a net load of 5,200 pounds, equals an output of 1,200 tons in 8 hours. Assuming that we limit the output to the same total, and allowing 23 seconds for changing six tubs, gives 60 seconds as the actual time of the wind.

The net load would be increased from 5,200 to 7,800 pounds; this would require a rope 1·25 inches in diameter, weighing $2\frac{3}{8}$ pounds per foot. The resulting increase in the total weight will be made up of 2,600 pounds of load, 3,000 pounds of rope, 1,988 pounds for the additional tubs, and, say, 2,400 pounds additional

weight of cages, or, in round numbers, 10,000 pounds. W_r will thus equal 79,700 pounds.

Assuming in this case that the engines were fitted with an automatic expansion-gear, giving an acceleration-curve similar to *A*.3. (Appendix II.), we have for the values of the respective coefficients, β equals $\frac{10}{7}$ and γ equals 2. Inserting these values in equation (61) gives:—

$$\lambda_r = \pm\sqrt{\left(\frac{F_{rm}\cdot g\cdot T^2}{W_r}\times\left(\frac{7}{4}\right)^2-\frac{5}{2}\cdot\lambda\right)^2-\left(\frac{5}{2}\cdot\lambda\right)^2}+\frac{F_{rm}\cdot g\cdot T^2}{W_r}\times\left(\frac{7}{4}\right)^2-\frac{5}{2}\cdot\lambda.$$

Taking the same tangential value for the cylinder-resistance, 2,690 pounds, and 4,220 pounds for the mean value of the unbalanced load during retardation, and an efficiency as before of 90 per cent., gives 7,677 pounds as the value of F_{rm}.

Therefore, $\frac{F_{rm}\cdot g\cdot T^2}{W_r}\times\left(\frac{7}{4}\right)^2-\frac{5}{2}\cdot\lambda=30,155.$

and $\lambda_r=\pm\sqrt{(30,155)^2-(4,038)^2}+30,155=272$ feet.

From equation (56):—

$$v=\frac{\frac{10}{7}(1,615)+\frac{4}{7}(272)}{60}=41 \text{ feet per second.}$$

The length of the wind during steam-admission will equal (1,615 − 272, or) 1,343 feet, and, by equation (2):—

$$(F.P.)g_t=(7,800+272\times 2\tfrac{2}{3})\times 1,343=11,449,075 \text{ foot-pounds.}$$

And the kinetic energy will equal

$$(F.P.)_a=\frac{79,700\times 41^2}{64\cdot 4}=2,080,330 \text{ foot-pounds.}$$

[redacted]

46·8 seconds and a_1 equals 2·63 feet per second, which is a much less initial acceleration than under the existing conditions.

The present mean effective steam-pressure for the first revolution, from the indicator diagrams, equals 43 pounds per square inch; and, assuming the load constant for the first revolution, and inserting values in equation (77), gives:—

$$D = \sqrt[3]{\frac{(12{,}107+6{,}500)\times 48\times 9{\cdot}7}{43\times 2\times 2\times 0{\cdot}9}} = 39 \text{ inches by } 6{\cdot}5 \text{ feet stroke}$$

or $= 40$ inches by 6 feet stroke.

As the present engines are over 42 inches in diameter, it is evident that they would be quite equal to the additional load; and, as a last illustration, we may ascertain the time in which the wind would be completed by the present engines with the heavier load.

The value of the initial accelerating force for the first revolution is equal to the total tangential force exerted by the engine minus the load at the lift.

$$\text{Therefore, } F_1 = \frac{1{,}365\times 43\times 4\times 6\times 0{\cdot}9}{2\times 3{\cdot}1416\times 9.7} - 12{,}107 = 8{,}697 \text{ pounds.}$$

The value of F_m is given by the equation under A.3. (Appendix II.) as $\frac{5}{21}.F_1$, which equals 2,071 pounds, and the value of the load at the end of the wind (L_2) equals (7,800−4,307, or) 3,493 pounds. The tangential retarding force in the cylinders equals, as before, 2,690 pounds, and inserting these values in equation (84) gives:—

$$\lambda_r = \pm\sqrt{\frac{1{,}615\times 1{,}864}{2\frac{2}{3}} + \left(\frac{2{,}690+3{,}493+1{,}864}{5\frac{1}{3}}\right)^2} - \frac{2{,}690+3{,}493+1{,}864}{5\frac{1}{3}} = 336{\cdot}6 \text{ feet.}$$

The value of the initial acceleration equals:—

$$a_1 = \frac{F_1\times g}{W_r} = \frac{8{,}697\times 32{\cdot}2}{79{,}700} = 3{\cdot}513 \text{ feet per second per second.}$$

The length of the wind under steam would equal (1,615−336·6 or) 1,278·4 feet, and from the equations for v and t_a under A.3. (Appendix II.):—

$$v = \sqrt{\tfrac{10}{21}\times 3{\cdot}513\times 1{,}278{\cdot}4} = 46{\cdot}2 \text{ feet per second.}$$

$$t_a = \frac{10\times 1{,}278{\cdot}4}{7\times 46{\cdot}2} = 39{\cdot}5 \text{ seconds.}$$

$$\text{and } t_r = \frac{2\times 336{\cdot}6}{46{\cdot}2} = 14{\cdot}6 \text{ seconds.}$$

The total time for the wind is thus 54·1 seconds, and allowing 20 seconds for changing the tubs, gives, say, 390 winds in 8 hours, which equals an output of 1,360 tons.

The kinetic efficiency under these conditions would equal 82·7 per cent. or a saving of 23·1 per cent. per wind on the present steam-consumption, without accounting for the further economy from the use of the steam expansively. It will thus be evident that a larger output could be raised with considerably greater economy than at present obtains.

The conditions for No. 5 plant might similarly be examined, but the examples given will suffice to illustrate the method. This paper has extended to considerably greater limits than was originally intended, but the writer trusts that he has succeeded in establishing the theory and testing of winding-plants upon a satisfactory basis, and that the results of his research will prove of interest and value in future tests.

In conclusion, the author conveys his sincere thanks to the owners and managers of the collieries who placed their plants at his disposal for the purpose of the tests, to the engineers and officials who rendered very acceptable assistance with the experiments, and particularly to Mr. A. Adams for his valuable cooperation in the preparation of Section VIII.

APPENDIX I.—SYNOPSIS OF FORMULÆ FOR VARYING TYPES OF ACCELERATION-

[redacted]

F_m = the mean tangential force in pounds, corrected for friction, for acceleration over the distance λ_a.

F_r = the initial tangential force in pounds, corrected for friction, required for retardation.

F_{rm} = the mean tangential force in pounds, corrected for friction, for retardation over the distance λ_r.

A.1. and R.1.—*Uniform acceleration and retardation.*

$$v = a_1.t_a = \sqrt{2a.\lambda_a}.$$

$$\lambda_a = \frac{a_1.t_a^2}{2} = \frac{v.t_a}{2}.$$

$$t_a = \frac{2\lambda_a}{v}.$$

$$\beta \text{ and } \gamma = 2. \qquad F_m = F_1. \qquad F_{rm} = F_r.$$

A.2.—*Uniformly decreasing acceleration from a_1 to a_0.*

$$v = \frac{a_1.t_a}{2} = \sqrt{\frac{3a_1.\lambda_a}{4}}.$$

$$\lambda_a = \frac{a_1.t_a^2}{3} = \frac{2v.t_a}{3}.$$

$$t_a = \frac{3\lambda_a}{2v}. \qquad \beta = \frac{3}{2}. \qquad F_m = \frac{3}{8}.F_1.$$

A.2.L.—*Uniformly decreasing acceleration between the limits a_1 and a_2 = where the final value a_2 is greater than nothing.*

$$v = a_1 t_a.\left(\frac{1+\rho}{2}\right) = \sqrt{\frac{3a_1.\lambda_a}{2}.\frac{(1+\rho)^2}{2+\rho}}.$$

$$\lambda_a = a_1 t_a^2.\left(\frac{2+\rho}{6}\right) = \frac{vt_a}{3}\left(\frac{2+\rho}{1+\rho}\right).$$

$$t_a = \frac{\lambda_a}{v}.\frac{3(1+\rho)}{2+\rho}. \qquad \beta = \frac{3(1+\rho)}{2+\rho}. \qquad F_m = \frac{3}{4}.\frac{(1+\rho)^2}{2+\rho}.F_1$$

where $\rho = \frac{a_2}{a_1}$ and is less than unity.

R.2.—*Uniformly decreasing retardation from a_{r_1} to a_{r_0}.*

$$v = \frac{a_{r_1}.t_r}{2} = \sqrt{\frac{3a_{r_1}.\lambda_r}{2}}.$$

$$\lambda_r = \frac{a_{r_1}.t_r^2}{6} = \frac{v.t_r}{3}.$$

$$t_r = \frac{3\lambda_r}{v}. \qquad \gamma = 3. \qquad F_{rm} = \frac{3}{4}.F_r.$$

R.2.L.—*Uniformly decreasing retardation between the limits a_{r_1} and a_{r_2}, where the final value a_{r_2} is greater than nothing.*

Exactly the same formulæ apply as in A.2.L, but in terms of a_{r_1} and except that $\rho = \frac{a_{r_1}}{a_{r_2}}$ and is greater than unity.

Parabolic Acceleration and Retardation.

A.3. (Fig. 4).—*Decreasing acceleration from a_1 to a_0.*

$$v = \frac{a_1.t_a}{3} = \sqrt{\frac{10a_1.\lambda_a}{21}}.$$

$$\lambda_a = \frac{7}{30}.a_1 t_a^2 = \frac{7}{10}.vt_a.$$

$$t_a = \frac{10}{7}.\frac{\lambda_a}{v}. \qquad \beta = \frac{10}{7}. \qquad F_m = \frac{5}{21}.F_1.$$

A.4. (Fig. 4).—*Decreasing acceleration from a_1 to a_0.*

$$v = \frac{2}{3} \cdot a_1 . t_a = \sqrt{\frac{10 a_1 \lambda_a}{9}}.$$

$$\lambda_a = \frac{2}{5} \cdot a_1 \, t_a^2 = \frac{3}{5} \cdot v t_a.$$

$$t_a = \frac{5}{3} \cdot \frac{\lambda_a}{v}. \qquad \beta = \frac{5}{3}. \qquad F_m = \frac{5}{9} \cdot F_1 .$$

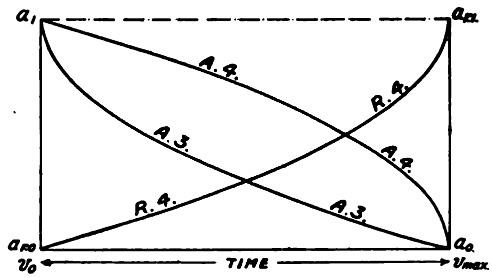

FIG. 4.—PARABOLIC ACCELERATION CURVES.

A.4. L.—*Decreasing acceleration on the same curve between the limits a_1 and a_2, where the final value a_2 is greater than nothing.*

$$v = a_1 . t_a \left(\frac{2+\rho}{3} \right) = \sqrt{\frac{10 a_1 . \lambda_a}{9} \cdot \frac{(2+\rho)^2}{4+\rho}}.$$

$$\lambda_a = a_1 . t_a^2 \left(\frac{4+\rho}{10} \right) = \frac{3 v t_a}{10} \left(\frac{4+\rho}{2+\rho} \right).$$

$$t_a = \frac{\lambda_a}{v} \cdot \frac{10(2+\rho)}{3(4+\rho)}. \qquad \beta = \frac{10(2+\rho)}{3(4+\rho)}. \qquad F_m = \frac{5(2+\rho)^2}{9(4+\rho)} \cdot F_1 .$$

where $\rho = \frac{a_2}{a_1}$ and is less than unity.

[redacted]

A.6. (Fig. 5).—*Decreasing acceleration from a_1 to a_0.*

$$v=\frac{2}{3}.a_1t_a=\sqrt{\frac{16a_1.\lambda_a}{15}}.$$

$$\lambda_a=\frac{5}{12}.a_1t^2_a=\frac{5}{8}.vt_a.$$

$$t_a=\frac{8}{5}.\frac{\lambda_a}{v} \qquad \beta=\frac{8}{5} \qquad \mathrm{F}_m=\frac{8}{15}.\mathrm{F}_1.$$

A.6. L.—*Decreasing acceleration on the same curve between the limits a_1 and a_2, where the final value a_2 is greater than nothing.*

$$v=a_1t_a\left(\frac{2+\rho}{3}\right)=\sqrt{\frac{4a_1.\lambda_a}{3}.\frac{(2+\rho)^2}{5+\rho}}.$$

$$\lambda_a=a_1.t_a^2\left(\frac{5+\rho}{12}\right)=\frac{vt_a}{4}\left(\frac{5+\rho}{2+\rho}\right).$$

$$t_a=\frac{\lambda_a}{v}.\frac{4(2+\rho)}{5+\rho} \qquad \beta=\frac{4(2+\rho)}{5+\rho} \qquad \mathrm{F}_m=\frac{2(2+\rho)^2}{3(5+\rho)}.\mathrm{F}_1.$$

where $\rho=\frac{a_2}{a_1}$ and is less than unity.

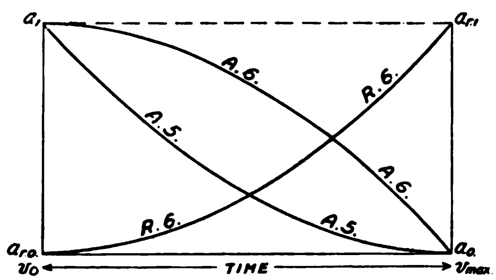

FIG. 5.—PARABOLIC ACCELERATION CURVES.

R.6. (Fig 5).—*Decreasing retardation from a_{r1} to a_{r0}.*

$$v=\frac{a_{r1}.t_r}{3}=\sqrt{\frac{4a_{r1}.\lambda_r}{3}}.$$

$$\lambda_r=\frac{a_{r1}.t_r^2}{12}=\frac{vt_r}{4}.$$

$$t_r=\frac{4\lambda_r}{v} \qquad \gamma=4 \qquad \mathrm{F}_{rm}=\frac{2}{3}\mathrm{F}_r.$$

R.6. L.—*Decreasing retardation between the limits a_{r1} and a_{r2}, where the final value a_{r2} is greater than nothing.*

Exactly the same formulæ apply as in A.6.L., but in terms of a_{r1} and except that $\rho=\frac{a_{r1}}{a_{r2}}$ and is greater than unity.

Hyperbolic Acceleration.

A.7.—*Decreasing acceleration on a hyperbolic curve between the limits a_1 and a_2, where the final value a_2 is greater than nothing.*

$$v=a_1.t_a\frac{1+\log_e\rho}{\rho}=\sqrt{\frac{2a_1.\lambda_a(1+\log_e\rho)^2}{1+2\rho.\log_e\rho}}$$

$$\lambda_a = a_1 . t_a^2 \frac{1+2\rho.\log_e\rho}{2\rho^2} = v.t_a \frac{1+2\rho.\log_e\rho}{2\rho(1+\log_e\rho)}$$

$$t_a = \frac{\lambda_a}{v} . \frac{2\rho(1+\log_e\rho)}{1+2\rho.\log_e\rho} \quad \beta = \frac{2\rho(1+\log_e\rho)}{1+2\rho.\log_e\rho}$$

$$F_m = \frac{(1+\log_e\rho)^2}{1+2\rho.\log_e\rho} . F_1$$

where $\rho = \frac{a_1}{a_2}$ and is greater than unity.

Of the above formulæ, A.2., A.4., and A.6. are of application to winding-engines running without expansion-gear, A.6. approximating to uniformly decreasing acceleration on a space base, that is, where the accelerating force decreases at a uniform rate per revolution. A.3., A.5. and A.7. are of application to winding-engines fitted with automatic expansion-gear operated by a governor, where the effective steam-pressure and rate of acceleration decrease rapidly for the first few revolutions. R.4. approximates to uniformly decreasing retardation on a space base, that is, where the net load or retarding force uniformly decreases per revolution.

APPENDIX II.

Suggested Regulations for the Testing of Winding-plants.

(1) *General Procedure.*—No steam-consumption test of a winding-plant can be considered conclusive in its results, unless it is accompanied by a complete dynamic test to determine the mechanical and kinetic efficiencies, and therefrom the actual mechanical energy developed per wind.

The test should be carried out under working conditions, provided arrangements can be made to run the winding-plant with steam supplied exclusively from separate boilers. Allowances and deductions for steam supplied to other plant are inaccurate and misleading.

If the above conditions can only be obtained after working-hours, the test should be made by successively winding the same net load in the shaft, the weight being fixed at the average for the shift and the precaution taken to run back with the steam-valve closed.

[redacted]

The observer in charge of the boilers should see that the pressure is kept below the blowing-off point and in the absence of a recording steam gauge should take a record of the pressure at intervals of ten minutes.

If the test includes the determination of the coal consumption, the temperature of the feed-water should be taken on the intake and discharge sides of the economiser or feed-heater if any.

An additional observer should record the weight of fuel delivered to the firing platform and the weight remaining unburned at the conclusion of the test.

(3) *Indicating of the Engines.*—Two observers with assistants should be in charge of the engine-house, one to take indicator-diagrams, and one in charge of the speed-recording apparatus, etc.

Diagrams should be taken at intervals of not more than 10 minutes, and an equal number from either end of each cylinder.

The total number of winds per hour with the exact time of each wind and the time under steam should be recorded on some form of tachometer similar in principle to that described in this paper (fig. 2).

In the absence of some such instrument, two additional observers with centre-seconds stop-watches would be required.

Instructions should be given to the engineman to wind precisely at the usual rate for full output and to shut off steam, as nearly as possible, at the same number of revolutions each trip.

(4) *Net Effective Work.*—Instructions should be given to the banksman to record the total number of winds of coal, materials, and men, together with empty runs, if any.

Instructions should be given to the machine weighman to record the total number of tubs drawn, with their total and average weights.

(5) *Dynamic test.*—At the conclusion of the steam test, a test should be made to determine the mechanical and kinetic efficiences of the plant, the net load being fixed at the average weight per wind during the steam trials.

Continuous indicator diagrams should be taken on both cylinders, winding at slow speed with the load on both the overlap and underlap ropes.

Similar complete diagrams should be taken at full speed, shutting off steam at the same average point as in the steam test.

The balance of the cages and ropes on either side should be tested, and any necessary correction applied to the calculation of the net effective work.

These tests will furnish the necessary data to determine the distribution of energy with the indicated, mechanical, and effective horsepowers.

(6) *Electric Winding-plants.*—In the application of these regulations to the testing of electric winders, in addition to the above details, diagrams should be obtained from recording watt-meters, giving the electrical output from the generators to the converter and from the converter to the winding motor.

APPENDIX III.

TABLE I.—TEST OF NO. 1 WINDING-PLANT.

DIMENSIONS OF PLANT.

Engines.

Number of cylinders	two.
Nominal diameter of cylinders	42 inches.
Actual diameter of left-hand cylinder	$42\frac{3}{16}$,,

Actual diameter of right-hand cylinder	$42\frac{1}{8}$ inches.
Diameter of piston-rod	6·5 „
Diameter of tail-rod	6·0 „
Net effective piston-area	1,365 square „
Length of stroke	6 feet.
Length of connecting-rod	15 feet.

Winding-drum.

Circumference at the lift	60 feet 6 inches.
Circumference at the last lap	60 feet 10 inches.
Mean circumference at the rope centre	60·94 feet.
Mean diameter at the rope centre	19·40 „
Width	6·50 „
Estimated approximate weight	20·0 tons.

Pit-head Pulleys.

Diameter on the rope-groove	14 feet.
Estimated weight of each	42 cwts.

Winding-ropes.

Diameter	$1\frac{1}{8}$ inches.
Estimated breaking-strain	60 tons.
Factor of safety on the static load	7·6
Total length	2,100 feet.
Total weight of each rope	4,112 pounds.
Weight of rope per foot	1·95 „
Weight of rope in the shaft	3,150 „

Cages.

Number of decks	two.
Estimated weight of each cage	50 cwts.
Weight of chains, etc.	15 „
Total weight of each cage and tackle	65 „

Pit-head Frame.

[redacted]

Slow-speed Wind—Load on Overlap Rope.

Observed Data.

Boiler pressure, pounds per square inch	65·0
Mean time of wind, in minutes	9·0

Indicator Diagrams.

Mean effective steam-pressure, pounds per square inch :—

Left-hand cylinder, back end	10·00
,, ,, front end	11·18
Right-hand cylinder, back end	10·67
,, ,, front end	10·36
Mean effective pressure	10·55

Calculated Results.

Net effective work, in foot-pounds	8,398,000
Indicated work, in foot-pounds	9,158,877
Mechanical efficiency of plant, per cent.	91·7

Full-speed Test—Load on Overlap Rope.

Observed Data.

Boiler pressure, pounds per square inch	63·0

Indicator Diagrams.

Mean effective steam pressure, pounds per square inch :—

Left-hand cylinder, back-end	20·4
,, ,, front-end	22·2
Right-hand cylinder, back-end	21·3
,, ,, front-end	23·1
Mean effective steam pressure	21·8
Number of revolutions under steam	18·5

Tachometer.

Mean time of wind, in seconds	44·25
Mean time under steam, in seconds	23·92
Maximum rope speed, in feet per second	69·20
Mean rope speed for the wind	36·80
Mean rope speed during acceleration	47·15
Maximum angular velocity per second	7·134
Maximum rate of acceleration, in feet per second per second	6·83
Mean rate of acceleration ,, ,, ,,	2·89
Mean rate of retardation ,, ,, ,,	3·41

Calculated Results.

Maximum piston-speed, in feet per minute	818·2
Moment of inertia of the winding drum, in ton-feet	43·0
Net effective work, in foot-pounds	8,398,000
Indicated work, in foot-pounds	13,212,108
Kinetic efficiency, per cent.	63·6
Maximum indicated horse power	1075
Mean indicated horse-power	1004
Mean mechanical horse-power	920
Mean effective horse-power	345

TABLE III.—TEST OF No. 2 WINDING-PLANT.

DIMENSIONS OF PLANT.

Engines.	
Number of cylinders	two.
Nominal diameter of cylinders	24 inches.
Actual diameter of left-hand cylinder	$24\frac{1}{4}$,,
Actual diameter of right-hand cylinder	$24\frac{3}{8}$,,
Diameter of piston-rod	3·5 ,,
Diameter of tail-rod	—
Net effective piston area	459·5 square ,,
Length of stroke	4 feet.
Length of connecting-rod	9 feet 1·5 inches.
Winding-drum.	
Circumference at the lift	38 feet 10 inches.
Circumference at the last lap	39 feet 4 inches.
Mean circumference at the rope centre	39·27 feet.
Mean diameter at the rope centre	12·50 ,,
Width	8·0 ,,
Estimated approximate weight	10·0 tons.
Pit-head pulleys.	
Diameter on the rope groove	11·5 feet.
Estimated weight of each	23 cwts.
Winding-ropes.	
Diameter	$1\frac{3}{8}$ inches.
Estimated breaking strain	40 tons.
Factor of safety on the static load	10·0
Total length	1,080 feet.
Total weight of each rope	2,162 pounds.
Weight of rope per foot	2·0 ,,
Weight of rope in the shaft	1,355 ,,

[redacted]

Details of the Load.

Weight of cages and tackle, in pounds	5,796	
Weight of winding-ropes ,, ...	4,324	
Weight of four tubs ,, ...	2,240	
		12,360
Net weight of coal, in pounds		3,472
Total weight to be set in motion, in pounds		15,832
Ratio of net load to total weight, per cent.		21·93

SLOW-SPEED TEST.

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	50
Mean time of wind, in minutes ...	—	—	6·0
Indicator Diagrams.			
Mean effective steam pressure, pounds per square inch:—			
Left-hand cylinder, back end ...	21·31	21·09	
,, ,, front end ...	21·68	21·46	
Right-hand cylinder, back end ...	19·49	20·91	
,, ,, front end ...	21·32	21·82	
Mean effective pressure	20·95	21·32	21·18
CALCULATED RESULTS.			
Net effective work, in foot-pounds ...	—	—	2,351,933
Indicated work, in foot-pounds ...	2,656,921	2,703,845	2,680,383
Mechanical efficiency of plant per cent.	88·52	86·98	87·75

FULL-SPEED TEST.

OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	50
Indicator Diagrams.			
Mean effective steam pressure, pounds per square inch:—			
Left-hand cylinder, back-end ...	37·4	—	
,, ,, front-end ...	33·4	—	
Right-hand cylinder, back-end ...	34·3	—	
,, ,, front-end ...	31·4	—	
Mean effective pressure	34·1	—	34·1
Number of revolutions under steam	—	—	12·5
Tachometer.			
Mean time of wind, in seconds ...	—	—	26·4
Mean time under steam...	—	—	18·07
Maximum rope speed, in feet per second	—	—	44·0
Mean rope speed for the wind ...	—	—	25·6
Mean rope speed during acceleration ...	—	—	27·1
Maximum angular velocity per second	—	—	7·04
Maximum rate of acceleration, in feet per second per second	—	—	5·20

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
Mean rate of acceleration, in feet per second per second	—	—	2·43
Mean rate of retardation, in feet per second per second	—	—	5·28
Calculated Results.			
Maximum piston speed, in feet per minute	—	—	540
Moment of inertia of winding-drum, in ton-feet	—	—	5·57
Net effective work, in foot-pounds ...	—	—	2,351,933
Indicated work, in foot-pounds ...	—	—	3,133,790
Kinetic efficiency, per cent.	—	—	75·05
Maximum indicated horse-power ...	—	—	425
Mean indicated horse-power	—	—	315
Mean mechanical horse-power ...	—	—	277
Mean effective horse-power ...	—	—	215

Table V.—Test of No. 3 Winding-plant.
Dimensions of Plant.

Engines.	
Number of cylinders	two.
Nominal diameter of cylinders	40 inches.
Actual diameter of cylinders	$40\frac{3}{8}$,,
Diameter of piston-rod	$5\frac{13}{16}$,,
Diameter of tail-rod	$4\frac{13}{16}$,,
Net effective piston area	1,258 square ,,
Length of stroke	5·5 feet.
Length of connecting-rod	15·0 ,,
Winding-drum.	
Circumference at the lift	61·75 ,,
Circumference at the last lap	61·75 ,,

[redacted]

Pit-head Frame.

Height to centre of pulleys	45 feet.
Horizontal distance from the centre of engine shaft to pit shaft	84 ,,

TABLE VI.—RESULTS OF DYNAMIC TEST OF NO. 3 WINDING-PLANT.

Date of Test	July 23rd, 1907.
Time	6.0 to 9.15 p.m.

GENERAL DATA.

Depth of wind in feet		1,138
Number of revolutions of engine		18¼
Details of the Load.		
Weight of cages and tackle, in pounds	13,440	
Weight of winding-ropes ,, ...	7,004	
Weight of twelve tubs ,, ...	6,188	
		26,632
Net weight of coal ,, ...		9,814
Total weight to be set in motion, in pounds		36,446
Ratio of net load to total weight per cent.		26·92

SLOW-SPEED TEST.	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	50
Mean time of wind, in minutes ...	—	—	6·0
Indicator Diagrams.			
Mean effective steam pressure, pounds per square inch :—			
Left-hand cylinder, front-end ...	25·5	24·8	
,, ,, back-end ...	24·6	23·7	
Right-hand cylinder, front-end ..	26·5	23·8	
,, ,, back-end ...	22·5	23·9	
Mean effective pressure	24·78	24·05	24·41
CALCULATED DATA.			
Net effective work, in foot-pounds ...	—	—	11,168,332
Indicated work, in foot-pounds ...	12,573,207	12,202,808	12,388,007
Mechanical efficiency of plant, per cent.	88·8	91·5	90·2
FULL-SPEED TEST.			
OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	50
Indicator Diagrams.			
Mean effective steam pressure, pounds per square inch :—			
Left-hand cylinder, front-end ...	30·3	—	
,, ,, back-end ...	27·5	—	
Right-hand cylinder, front-end ...	31·5	—	
,, ,, back-end ...	31·7	—	
Mean effective pressure	30·25	—	30·25
Number of revolutions under steam	—	—	16·0

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Result.
Tachometer.			
Mean time of wind, in seconds ...	—	—	45·0
Mean time under steam...	—	—	37·0
Maximum rope speed, in feet per second	—	—	41·3
Mean rope speed for the wind... ...	—	—	25·3
Mean rope speed during acceleration...	—	—	26·8
Maximum angular velocity per second	—	—	4·18
Maximum rate of acceleration, in feet per second per second	—	—	2·20
Mean rate of acceleration, in feet per second per second	—	—	1·12
Mean rate of retardation, in feet per second per second	—	—	5·16
Calculated Results.			
Maximum piston speed, in feet per minute	—	—	440
Moment of inertia of winding-drum, in ton-feet	—	—	44·34
Net effective work, in foot-pounds ...	—	—	11,168,332
Indicated work, in foot-pounds ...	—	—	13,373,043
Kinetic efficiency, per cent.	—	—	83·5
Maximum indicated horsepower ...	—	—	840
Mean indicated horsepower	—	—	657
Mean mechanical horsepower	—	—	593
Mean effective horsepower	—	—	451

Table VII.—Test of No. 4 Winding-plant.

Dimensions of Plant.

Engines.

Number of cylinders ... ... two.

[redacted]

Factor of safety on the static load	10·5
Total length	1,950 feet.
Total weight	3802 pounds.
Weight of rope per foot	1·95 ,,
Weight of rope in the shaft	3,161 ,,

Balance-rope (Iron).

Circumference	$3\frac{3}{4}$ inches.
Total length	1,650 feet.
Total weight	4,042 pounds.
Weight of rope per foot	2·45 ,,

Cages.

Number of decks	one.
Weight, including tackle, left-hand	3,332 pounds.
Weight, including tackle, right-hand	3,032 ,,

Pit-head Frame.

Height to the centre of pulleys	45 feet.
Horizontal distance from the centre of engine shaft to pit shaft	88 ,,

TABLE VIII.—RESULTS OF DYNAMIC TEST OF No. 4 WINDING-PLANT.

Date of test ... ... November 22nd, 1907.
Time ... ... 3·0 to 7·0 p.m.

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
GENERAL DATA.			
Depth of wind, in feet	—	—	1,621
Number of revolutions of engine ...	—	—	$25\frac{1}{3}$
Details of the Load.			
Weight of cages and tackle, in pounds	6,364	6,364	
Weight of winding-rope, ,, ...	3,802	3,802	
Weight of balance-rope, ,, ...	4,042	4,042	
Weight of four tubs, ,, ...	1,946	1,946	16,154
Net weight of coal, ,, ...	3,360	3,360	
Overbalance of the heavier cage, in pounds	300	300	
Net unbalanced load	3,060	3,660	3,360
Total weight to be set in motion, in pounds	19,514	19,514	19,514
Ratio of net load to total weight, per cent.	15·68	18·76	17·22

SLOW-SPEED TEST.

OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	60
Mean time of wind, in minutes ...	—	—	8

Indicator Diagrams.

Mean effective steam pressure, pounds per square inch :—

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
Left-hand cylinder, back-end ...	26·51	31·80	
,, ,, front-end ...	30·48	34·05	
Right-hand cylinder, back-end ...	26·10	32·31	
,, ,, front-end ...	28·08	34·24	
Mean effective pressure	27·77	33·10	30·43
Calculated Results.			
Net effective work, in foot-pounds ...	4,960,260	5,932,860	5,446,560
Indicated work, in foot-pounds ...	5,618,626	6,697,030	6,157,828
Mechanical efficiency of plant, per cent.	88·3	88·6	88·45

Full-speed Test.

Observed Data.			
Boiler pressure, pounds per square inch	—	—	60·
Indicator Diagrams.			
Mean effective pressure, pounds per square inch :—			
Left-hand cylinder, back-end ...	32·46	—	
,, ,, front-end ...	30·95	—	
Right-hand cylinder, back-end ...	34·93	—	
,, ,, front-end ...	33·71	—	
Mean effective pressure	33·02	—	33·02
Number of revolutions under steam	—	—	22⅓
Tachometer.			
Mean time of wind, in seconds ...	—	—	68·0
Mean time under steam, in seconds ...	—	—	63·5
Maximum rope-speed, in feet per second	—	—	47·4
Mean rope-speed for the wind ...	—	—	23·8

[redacted]

TABLE IX.—TEST OF NO. 5 WINDING-PLANT.

DIMENSIONS OF PLANT.

Engines.	
Number of cylinders	two.
Nominal diameter of cylinders	36 inches.
Actual diameter of left hand cylinder	$36\frac{3}{8}$,,
Actual diameter of right hand cylinder	$36\frac{1}{4}$,,
Diameter of piston-rod	6·5 ,,
Diameter of tail-rod	6·5 ,,
Net effective piston area	1002·4 square ,,
Length of stroke	6 feet.
Length of connecting-rod	15 ,,
Winding-drum.	
Circumference at the lift	56 ,,
Circumference at the last lap	56 feet 2 inches.
Mean circumference at the rope centre	56·54 feet.
Mean diameter at the rope centre	17·84 ,,
Width	11·75 ,,
Estimated approximate weight	35·0 tons.
Pit-head Pulleys.	
Diameter on the rope groove	16 feet.
Estimated weight of each	60 cwts.
Winding-ropes.	
Diameter	1·75 inches.
Estimated breaking strain	135 tons.
Factor of safety on the static load	9·5
Total length	2,100 feet.
Total weight of each rope	11,273 pounds.
Weight of rope per foot	5·37 ,,
Weight of rope in the shaft	8,908 ,,
Cages.	
Number of decks	two.
Estimated weight of each	80 cwts.
Estimated weight of chains, etc.	20 ,,
Total weight of each cage and tackle	100 ,,
Pit-head Frame.	
Height to the centre of pulleys	75 feet.
Horizontal distance from the centre of engine-shaft to pit-shaft	119 ,,

TABLE X.—RESULTS OF DYNAMIC TEST OF NO. 5 WINDING-PLANT.

Date of test ... April 8th, 1908.

Time ... 5.30 to 9.0 p.m.

GENERAL DATA.	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
Depth of wind, in feet	—	—	1,659
Number of revolutions of engine	—	—	$29\frac{1}{3}$

Details of the Load.	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
Weight of cages and tackle, in pounds	22,400	22,400	
Weight of winding-ropes, ,,	22,546	22,546	
Weight of twelve tubs, ,,	7,868	7,868	52,814
Net weight of coal, ,, ...	7,304	7,304	
Overbalance of the heavier cage, in pounds	228	228	
Net unbalanced load	7,076	7,532	7,304
Total weight to be set in motion, in pounds	60,118	60,118	60,118
Ratio of net load to total weight, per cent.	11·77	12·53	12·15
SLOW-SPEED TEST.			
OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	100
Mean time of wind, in minutes ...	—	—	6
Indicator Diagrams.			
Mean effective pressure, pounds per square inch :—			
Left-hand cylinder, back-end ...	16·59	19·47	
,, ,, front-end ...	21·39	20·21	
Right-hand cylinder, back-end ...	19·94	20·50	
,, ,, front-end ...	16·46	19·57	
Mean effective pressure	18·60	19·94	19·27
CALCULATED RESULTS.			
Net effective work, in foot-pounds ...	11,739,084	12,495,588	12,117,336
Indicated work, in foot-pounds ...	13,125,826	14,071,434	13,598,630
Mechanical efficiency of plant, per cent.	89·43	88·80	89·11

[redacted]

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
Maximum rope speed, in feet per second	—	—	65·8
Mean rope speed for the wind	—	—	34·3
Mean rope speed during acceleration ...	—	—	39·8
Maximum angular velocity, per second	—	—	7·32
Maximum rate of acceleration, in feet per second per second	—	—	4·40
Mean rate of acceleration, in feet per second per second	—	—	2·44
Mean rate of retardation, in feet per second per second	—	—	3·09
CALCULATED RESULTS.			
Maximum piston-speed, in feet per minute	—	—	837
Moment of inertia of winding-drum, in ton-feet	—	—	32·06
Net effective work, in foot-pounds ...	11,739,084	—	
Indicated work, in foot-pounds ...	19,517,930	—	
Kinetic efficiency, per cent.	60·15	—	
Maximum indicated horsepower ...	1,620	—	
Mean indicated horsepower	1,314	—	
Mean mechanical horsepower	1,172	—	
Mean effective horsepower	442	—	

TABLE XI.—TEST OF No. 6 WINDING-PLANT.

DIMENSIONS OF PLANT.

Engines.	
Number of cylinders	two.
Diameter of both cylinders, actual	30 inches.
Diameter of piston-rod	5 ,,
Diameter of tail-rod	—
Net effective piston area	697 square inches.
Length of stroke...	5 feet.
Length of connecting-rod	12·5 ,,
Winding-drum.	
Circumference at the lift	49 feet 7 inches.
Circumference at last lap	49 ,, 7 ,,
Mean circumference at the rope centre	49·98 feet.
Mean diameter at the rope centre	15·90 ,,
Width	5 feet 4 inches.
Estimated approximate weight	14 tons.
Pit-head Pulleys.	
Diameter on the rope-groove	16 feet.
Estimated weight of each	60 cwts.
Winding-ropes.	
Diameter	1·5 inches.
Estimated breaking-strain	95 tons.
Factor of safety on the static load	10·5.

Total length	1,335 feet.
Total weight of each rope	4,925 pounds.
Weight of rope per foot	3·68 ,,
Weight of rope in the shaft	3,770 ,,

Cages.

Number of decks	two.
Estimated weight of each cage	50 cwts.
Estimated weight of chains, etc.	15 ,,
Total weight of each cage and tackle	65 ,,

Pit-head Frame.

Height to the centre of pulleys	50 feet.
Horizontal distance from the centre of engine shaft to pit shaft	91 ,,

Table XII.—Results of Dynamic Test of No. 6 Winding-plant.

Date of test	April 9th, 1908
Time	5.30 to 9.0 p.m.

General Data.	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
Depth of wind, in feet	—	—	1024·6
Number of revolutions of engine	—	—	20·5
Details of the Load.			
Weight of cages and tackle, in pounds	14,560	14,560	
Weight of winding-ropes, ,,	9,850	9,850	
Weight of eight tubs, ,,	5,340	5,340	29,750
Net weight of coal, in pounds	5,028	5,028	
Overbalance of the heavier cage, etc.	245	245	
Net unbalanced load, in pounds	4,783	5,273	5,028

[redacted]

	Load on Overlap Rope.	Load on Underlap Rope.	Mean Results.
CALCULATED RESULTS.			
Net effective work, in foot-pounds ...	4,900,662	5,402,716	5,151,689
Indicated work, in foot-pounds ...	5,303,891	5,875,431	5,589,661
Mechanical efficiency of plant, per cent.	92·39	91·96	92·17
FULL-SPEED TEST.			
OBSERVED DATA.			
Boiler pressure, pounds per square inch	—	—	110
Indicator Diagrams.			
Mean effective steam pressure, pounds per square inch :—			
Right-hand cylinder, back-end ...	35·36	—	
,, ,, front-end ...	31·22	—	
Left-hand cylinder, back-end	38·07	—	
,, ,, front-end	34·17	—	
Mean effective pressure	34·70		34·70
Number of revolutions under steam	... ...	... ...	14·50
Tachometer.			
Mean time of wind, in seconds ...	—	—	34·8
Mean time under steam...	—	—	20·4
Maximum rope speed, in feet per second	—	—	46·7
Mean rope speed for the wind	—	—	29·4
Mean rope speed during acceleration...	—	—	35·5
Maximum angular velocity, per second	—	—	5·87
Maximum rate of acceleration, in feet per second per second	—	—	8·20
Mean rate of acceleration, in feet per second per second	—	—	2·29
Mean rate of retardation, in feet per second per second	—	—	3·24
CALCULATED RESULTS.			
Maximum piston-speed, in feet per minute	—	—	560
Moment of inertia of winding-drum, in ton-feet	—	—	20·6
Net effective work, in foot-pounds ...	4,900,662	—	
Indicated work, in foot-pounds ...	7,013,911	—	
Kinetic efficiency, per cent.	69·87	—	
Maximum indicated horsepower ...	992	—	
Mean indicated horsepower	625	—	
Mean mechanical horsepower	576	—	
Mean effective horsepower	256	—	

[redacted]

[redacted]est of No. 1 Winding-plant. Energy Analysis.

Formulæ.	Full-speed Test.				Slow-speed Test.	
				Per Cent. of *I.F.P.*		Per Cent. of *I.F.P.*
I.F.P.	13,212,108			100·0	9,158,877	100·0
	1,096,605			8·3	760,877	8·3
$(F.P.)m$		12,115,503		91·7		
$(F.P.)g_t$		6,934,434	6,934,434			
$(F.P.)a_1$	2,376,474					
$(F.P.)a_2$	351,860					
	2,452,735					
$(F.P.)a$		5,181,069		39·2		
$(F.P.)g_r$		1,463,566	1,463,566			
$(F.P.)_{RL}$		3,717,503		28·1		
		336,434				
$(F.P.)_{KL}$		4,053,937		30·7		
$(F.P.)g$			8,398,000	63·6	8,398,000	91·7

TABLE XIV.—TEST OF NO. 2 WINDING-PLANT. ENERGY ANALYSIS.

Equation Reference Number.		Formulæ.	Full-speed Test.				Mean of Slow-speed Tests.	
						Per Cent. of *I.F.P.*		Per Cent. of *I.F.P.*
	Acceleration Period.							
29	Total indicated energy	*I.F.P.*	3,133,790			100·00	2,680,383	100·00
32	Total friction loss		383,889			12·25	328,450	12·25
6	Total mechanical energy	$(F.P.)m$		2,749,901		87·75		
2	Net effective work	$(F.P.)g_t$		1,887,224	1,887,224			
	Kinetic Energy.							
3	Ropes, cages, tubs, and coal ...	$(F.P.)a_1$	475,943					
4	Pit-head pulleys	$(F.P.)a_2$	77,440					
4	Winding-drum (by difference)		309,294					
5	Total kinetic energy	$(F.P.)a$		862,677		27·53		
	Retardation Period.							
37	Net effective work	$(F.P.)g_r$		464,709	464,709			
42	Retardation loss	$(F.P.)_{RL}$		397,968		12·70		
	Add co-efficient of friction loss ...			55,317				
44	Total kinetic loss	$(F.P.)_{KL}$		453,285		14·46		
1	Total effective work	$(F.P.)g$			2,351,933	75·05	2,351,933	87·75

[redacted]EST OF No. 3 WINDING-PLANT. ENERGY ANALYSIS.

Formulæ.	Full-speed Test.				Mean of Slow-speed Tests.	
				Per Cent. of $I.F.P.$		Per Cent. of $I.F.P.$
$I.F.P.$	13,373,043			100·0	12,388,007	100·0
	1,310,558			9·8	1,219,675	9·8
$(F.P.)m$		12,062,485		90·2		
$(F.P.)g_t$		10,081,267	10,081,267			
$(F.P.)a_1$	965,310					
	148,320					
$(F.P.)a_2$	867,588					
$(F.P.)a$		1,981,218		14·8		
$(F.P.)g_r$		1,087,065	1,087,065			
$(F.P.)_{RL}$		894,153		6·7		
		97,105				
$(F.P.)_{KL}$		991,258		7·4		
$(F.P.)g$			11,168,332	83·5	11,168,332	90·2

TABLE XVI.—TEST OF NO. 4 WINDING-PLANT. ENERGY ANALYSIS.

Equation Reference Number.		Formulæ.	Full-speed Test.				Mean of Slow-speed Tests.	
						Per Cent. of *I.F.P.*		Per Cent. of *I.F.P.*
	Acceleration and Full-speed Period.							
29	Indicated energy	*I.F.P.*	5,571,931					
32	Friction loss		643,558			11·55		
6	Mechanical energy	$(F.P.)m$		4,928,373				
14	Net effective work	$(F.P.)g_t$		3,547,716	3,547,716			
	Kinetic Energy.							
3	Ropes, cages, tubs and coal ...	$(F.P.)a_1$	680,796					
4	Pit-head pulleys	$(F.P.)a_2$	179,639					
4	Winding-drum (by difference)		520,222					
5	Total kinetic energy	$(F.P.)a$		1,380,657		22·76		
	Retardation Period.							
	Indicated energy	*I.F.P.*	493,572					
	Less friction loss		57,007			11·55		
	Additional mechanical energy ...	$(F.P.)m$		436,565				
				1,817,222				
39	Net effective work	$(F.P.)g_r$		1,412,544	1,412,544			
42	Retardation loss	$(F.P.)_{RL}$		404,678		6·67		
	Add co-efficient of friction loss ...			52,850				
44	Total kinetic loss	$(F.P.)_{KL}$		457,528		7·54		
1	Total effective work	$(F.P.)g$			4,960,260	81·78	5,446,560	88·45
6	Total mechanical work	$(F.P.)m$			5,364,938	88·45		
32	Total friction loss				700,565	11·55	711,268	11·55
29	Total indicated work	*I.F.P.*			6,065,503	100·00	6,157,828	100·00

[redacted]

TEST OF No. 5 WINDING-PLANT. ENERGY ANALYSIS.

Formulæ.	Full-speed Test.				Mean of Slow-speed Tests.	
				Per Cent. of *I.F.P.*		Per Cent. of *I.F.P.*
I.F.P	19,517,930			100·00	13,598,630	100·00
	2,125,503			10·89	1,481,294	10·89
$(F.P.)_m$		17,392,427		89·11		
$(F.P.)_{g_t}$		10,974,834	10,974,834			
$(F.P.)_{a_1}$	4,041,733					
$(F.P.)_{a_2}$	451,785					
	1,924,075					
$(F.P.)_a$		6,417,593		32·88		
$(F.P.)_{g_r}$		764,250	764,250			
$(F.P.)_{RL}$		5,653,343		28·96		
		690,838				
$(F.P.)_{KL}$		6,344,181		32·50		
$(F.P.)_g$			11,739,084	60·15	12,117,336	89·11

TABLE XVIII.—TEST OF NO. 6 WINDING-PLANT. ENERGY ANALYSIS.

Equation Reference Number.		Formulæ.	Full-speed Test.				Mean of Slow-speed Tests.	
						Per Cent. of *I.F.P.*		Per Cent. of *I.F.P.*
	Acceleration Period.							
29	Total indicated energy	$I.F.P.$	7,013,911			100·00	5,589,661	100·00
32	Total friction loss		549,189			7·83	437,972	7·83
6	Total mechanical energy	$(F.P.)m$		6,464,722		92·17		
2	Net effective work	$(F.P.)g_t$		4,266,019	4,266,019			
	Kinetic Energy.							
3	Ropes, cages, tubs, and coal ...	$(F.P.)a_1$	1,177,583					
4	Pit-head pulleys	$(F.P.)a_2$	227,539					
4	Winding-drum (by difference)		793,581					
5	Total kinetic energy	$(F.P.)a$		2,198,703		31·34		
	Retardation Period.							
37	Net effective work	$(F.P.)g_r$		634,643	634,643			
42	Retardation loss	$(F.P.)_{RL}$		1,564,060		22·30		
	Add co-efficient of friction loss ...			132,945				
44	Total kinetic loss	$(F.P.)_{KL}$		1,697,005		24·20		
1	Total effective work	$(F.P.)g$			4,900,662	69·87	5,151,689	92·17

APPENDIX IV.

Table XIX.—Comparative Results of Steam-consumption Tests on No. 2 Winding-plant.

Date of test	Nov. 7th, 1907	Nov. 11th, 1907
Time : Taking indicator-cards, right-hand cylinder	6.54 to 7.54 p.m.	6.33 to 7.33 p.m.
Changing over indicator, etc. ...	7.54 to 8.25 ,,	7.33 to 8.0 ,,
Taking indicator-cards, left-hand cylinder	8.25 to 9.13 ,,	8.0 to 8.53 ,,
General Data.		
Depth of wind, in feet	677·40	677·40
Net weight of coal raised per wind, in pounds	3,472	3,472
Total revolutions of engine per trip ...	17·25	17·25
Observed Data.		
Mean boiler pressure, pounds per square inch	49·00	49·00
Indicator Diagrams.		
Mean effective pressure, pounds per square inch :—		
Right-hand cylinder, back-end ...	34·62	34·85
,, ,, front-end ...	34·82	34·90
Left-hand cylinder, back-end	35·86	35·91
,, ,, front-end	33·76	33·81
Mean effective pressure	34·76	34·87
Number of revolutions under steam	12·50	11·00
Tachometer.		
Total number of winds	75	85
Actual duration of test	1h. 48m.	1h. 53m.

[redacted]

Mechanical work per wind, in foot-pounds	2,804,353	2,474,552
Total mechanical horsepower-hours ...	106·2	106·2
Net effective work per wind, in foot-pounds	2,351,933	2,351,933
Total effective horsepower-hours ...	89·1	100·9
Kinetic efficiency, per cent.	73·6	83·4
Steam Consumption.		
Total quantity of steam used, in pounds	10,725	10,637
Steam per indicated horsepower-hour, in pounds	88·6	87·9
Steam per mechanical horsepower-hour, in pounds	100·9	100·1
Steam per effective horsepower-hour, in pounds	120·3	105·4
Increase in kinetic efficiency, per cent.	—	9·8
Corresponding saving in indicated work per wind, per cent.	—	11·7
Resulting saving in steam-consumption, per cent.	—	12·3

TABLE XX.—STEAM-CONSUMPTION TEST OF NO. 5 WINDING-PLANT.

Date of test	April 8th, 1908
Time: Duration of test	12.0 to 4.0 p.m.
Taking indicator cards, right-hand cylinder	12.0 to 1.50 ,,
Taking indicator cards, left-hand cylinder	2.20 to 4.0 ,,
GENERAL DATA.	
Depth of wind, in feet	1,659
Total weight of coal and dirt raised, in tons	266·9
Total number of tubs	491
Average net weight per wind, in pounds	7,304
Total number of winds of coal and dirt	82
Total number of winds of men and empties	3
Total revolutions of engine per wind	29⅓
OBSERVED DATA.	
Mean boiler pressure, pounds per square inch	100
Indicator Diagrams.	
Mean effective pressure, pounds per square inch :—	
Right-hand cylinder, back-end	42·00
,, ,, front-end	46·97
Left-hand cylinder, back-end	44·31
,, ,, front-end	50·99
Mean effective pressure	46·07
Mean number of revolutions under steam	18·0
Tachometer.	
Actual duration of test	4h. 0m.
Actual time of winding	1h. 8m.
Actual time under steam	0h. 38·2m.

Ratio of time of winding to duration of test, per cent.	28·3
Ratio of time under steam to duration of test, per cent.	15·9
Mean time of wind, in seconds	48·0
Mean time under steam, in seconds	27·0
Calculated Results.	
Indicated work per wind on the load, in foot-pounds	19,950,005
Indicated work per wind of men and empties, estimated at 50 per per cent., in foot-pounds	9,975,002
Total indicated horsepower-hours	841·33
Mean indicated horsepower on the load	1,343·4
Mechanical efficiency per cent. from dynamic test	89·11
Total mechanical horsepower-hours	749·70
Net effective work per wind on the load, in foot-pounds ...	12,117,336
Net effective work per wind of men and empties, estimated at 50 per cent., in foot-pounds	6,058,668
Total effective horsepower-hours	510·11
Kinetic efficiency per wind on the load, per cent.	60·74
Mean kinetic efficiency over the whole test...	60·63
Steam Consumption.	
Total quantity of steam used, in pounds	65,084
Less estimated consumption of pump :—	
Details :—Cylinder, 10 inches diameter by 15 inches stroke	
Piston speed, 44 feet per minute, steam pressure 18 pounds	
Time of running, 1·30 p.m. to 2·30 p.m.	
Estimated weight of steam, in pounds	234
Net steam consumption of winding-engines	64,850
Steam per indicated horsepower-hour, in pounds	77·1
Steam per mechanical horsepower-hour ,, ...	86·5
Steam per effective horsepower-hour ,, ...	127·1

[redacted]

was fitted with a Kœpe drum; in that case the drum would be a very light one; and, if the engines were fitted with a balance-rope, it appeared to him that with a drum of that character, with the advantage of the weight of the balance-rope, the 4·1 per cent. was not a percentage which would be applicable to the heavier types of drums, and in all cases.

Another point which struck him was this: assuming that the 4·1 per cent. was sufficient to turn the engines and the pulleys, that would leave a margin of 28 per cent., taking the 32 per cent. as being what the author had calculated as the wasted energy applicable to the tests which he had made. Was that wasted energy of 28 per cent. represented by the inefficiency of the design, or was it represented by the wire-drawing incidental to the cylinders not being able to fill themselves effectively when running at high speed, and to back-pressure also? With regard to the weight of the balance-rope, the author had stated that in one test his balance-rope was considerably heavier than the winding-rope. He would like the author to give some information as to the economy or otherwise of that arrangement. He knew that some of their friends advocated the balance-rope being heavier than the winding-rope, owing to the great assistance which it gave to the load leaving the bottom, and to the fact that the slight retardation when nearing the top, owing to the heavier balance-rope, was not objectionable, seeing that it prevented to some extent the danger of overwinding or the cage going too far above the kips. He moved that a very cordial vote of thanks be given to Mr. Thacker for the most able paper he had presented.

Mr. Isaac Hodges (Normanton) said that Mr. Thacker's paper gave abundant food for thought. In thinking over the question as to designing a winding engine to suit the work exactly to be done, he had come to the conclusion that it was almost impossible for a colliery manager to describe to a mechanical engineer the exact conditions under which the engine might be expected to work for any considerable period of its life. No one could foresee what an engine would be expected to do in its later life, and they must all, therefore, design their engines with a large margin of power, which in itself tended to make that engine a less efficient machine. When mines were sunk, as many were nowadays, with permanent winding-engines, there were many

factors to be taken into consideration, such as the quality of the seams and the output from each seam that would best suit the markets. He was able to point to an engine which was built in 1872 to wind 800 tons per day from a depth of 1,260 feet. It was an excellently designed engine for its time, and exceedingly strong; but at the present time they were winding 2,500 tons per day with that same engine from the same depth. If the mechanical engineer of that period had designed the winding engine to deal with the large load, it was to be assumed that it would have really been able to have raised something like 5,000 or 6,000 tons. He could only say that the faults of that period were a great benefit to the company that owned the engine, and although it had now reached the more powerful stage when he thought that it should be removed and replaced by a larger engine, still he must say that he had been profoundly grateful for the original designer in having made such liberal allowances in his calculations.

He agreed with what the author had said as to the impossibility of calculating steam-efficiencies from indicator diagrams alone, and that it must be done by taking the actual weight of water evaporated. There were so many chances of loss that the calculation of the amount of steam used when taken only from the diagrams became far too unreliable. He had much pleasure in seconding the vote of thanks.

Mr. Thomas Turner (Kilmarnock) said that the author was [redacted]

The defects in old engines were now prominent because of increase in the speed of winding. Such speeds of winding had not been contemplated when engines were built twenty or thirty years ago. The engines, however, existed, and mine-owners had to put up with them.

One of the steps towards progress in excluding such defects had been the development—largely influenced, he thought, by what had been done in South Africa—of the use of Corliss engines for winding, which not only had steam waste by clearances reduced down to perhaps 4 per cent., but were also excellently adapted for the application of governor control, which, of course, permitted of maximum and determined speeds being used, although at the same time minimizing the quantity of steam used. There was an objection in the minds of some to the use of a governor, because of the control which it took out of the hands of the winding-enginemen. But when a governor had a throw-out attachment provided, so as to allow the man to cut out the governor control and to use his own influence at any part of the wind, as was now the usual practice, there was no reason why it should be regarded as in any way carrying any risk into the process of winding.

Mine-owners could not, however, remove their existing plants in every case, and to remedy the engine and valve defects indicated by the author (which, of course, were the prime details that controlled the excellence of the plant), they could only, after testing or taking indicator diagrams, use additions to their valve-gear, or modifications. One way to remedy the serious back-pressure that occurred in drop-valve engines, of which many existed, was to alter their exhaust-levers, so as to lift the exhaust-valve quickly and hold it open during the whole stroke, letting it drop quickly at the end. On most existing engines, the sluggish opening and early closing action was a serious defect.

There were ways which he and other engineers had put forward for dealing with that, and it was really worth anybody's while to take particular notice in engine designing of the mode of lifting the exhaust-valve quickly, holding it open during the whole stroke, and letting it drop quickly at the end, as in that way they would remove a good deal of the back-pressure. A much more effective method, however, of removing back-pressure (which occurred more especially during the full-speed period

of winding) was to apply a governor, if the length of wind justified it. That, of course, cut off the steam at an early portion of the stroke, and allowed it to expand to the end of the stroke, where it exhausted at a low pressure. The saving of steam was therefore twofold, obtained, first, by cutting off early, and, secondly, by the removal of back-pressure.

On many slide-valve winding-engines for small plants the readiest way to economize steam was to put a cut-off valve either within or just outside the steam-chest, operated by some gear which would enable one to cut off immediately after the start of the winding. He had had the pleasure and satisfaction of fitting such valves and simple gear, which, by cutting off and removal of back-pressure as he had indicated, saved in some cases 40 per cent., and in other cases 50 and even 53½ per cent., of the steam used. That large saving was obtained on winding-engines of ordinary slide-valve design. So considerable an economy seemed almost impossible; but when it was remembered that in some cases winding-engines were faulty in the passages to which he had referred, and in the gear, and also were rather large for the work they did, and probably faulty in valve-setting, it would be seen that those improvements of efficiency in steam-consumption became possible. Winding-engines were designed large, because they had to make considerable effort at the beginning of the stroke. But that large amount was not required after the first two or three revolutions, and therefore it was [redacted]

if a considerable number of tons of coal more could be got out of the pit per day. One threw the work into the brakes to pull up quickly to get started for the next run, and that was desirable in many cases.

Reverting to the point of back-pressure, the loss due to which was a most serious thing, he might mention that one frequently came across engines built by those who were recognized as good makers at one time, with exhaust-valves no larger than the steam-valves, and even the exhaust-passages similarly throttled. When that occurred on drop-valve engines, practically the only remedy was to remove the valve-chest entirely, as he knew had been done in certain cases.

Mr. B. WOODWORTH (Dresden) wrote that he would confine his remarks to the main guiding principles necessary for such work as described by the author to be done to the best advantage. It was not practicable to arrange work such as winding-engines have to do in such a manner that all the surplus power used in acceleration (less friction, etc.) may be utilized during the retardation period, as in most cases it would cause too much delay in the work; but the nearer that point could be reached the better, and that was the most important part to be considered when laying out such work.

The old adage that it is the pace that kills held good in the matter of economy, and there were doubtless numerous cases where, if the load were increased by 50 or even 80 per cent., and the pace moderated to suit, it would be proved to be of great economical advantage. The spiral drum could be proportioned for fairly even working, but when its great weight was taken into consideration, along with the troubles of adjustments or emergency working, he (Mr. Woodworth) considered that its disadvantages were too serious, and he should prefer to adopt the two fast ropes working on a parallel, or practically a parallel, drum, combined with the use of balance-rope working (either simple or modified system); and if the balance-rope could be safely used with an excess weight of 10 to 20 per cent., as suggested in the writer's paper on winding from a depth of 3,000 feet,* it helped both the acceleration and retardation work in a

* "Proposed Plant for Winding 250 Tons of Coal per Hour from a Depth of 3,000 feet," by Mr. B. Woodworth, *Trans. Inst. M. E.*, 1905, vol. xxx., page 31.

proper manner, and would enable one to secure all that was possible in the way of using up the surplus acceleration power in the most effective manner in combination with a maximum of speed in the working.

With regard to the tests of the separate plants named in the paper, he (Mr. Woodworth) was afraid that the water had been a source of error in the diagrams from No. 1 plant, as the margin between indicated and shaft-load duty (at slow speeds) was too small to be a fair allowance for all the other losses. He (Mr. Woodworth) submitted a few comparative figures for the whole series, for ready reference:—

No. of Test.	Shaft-Load Efficiency.	Average Pressure.	Margin for Other Losses.	Slow-speed Power.	Quick-speed Power.	Maximum Rope-speed.	Maximum Drum-Revolutions.
	Per cent.	Pounds.	Pounds.			Feet per Second.	Per Second.
1	91·70	10·55	about 0·87	as 1·00	to about 2·00	69·2	about 1·14
2	87·75	21·18	nearly 2·60	as 1·00	to over 1·60	44·0	about 1·10
3	90·20	24·41	nearly 2·40	as 1·00	to under 1·25	41·3	about 0·66
4	88·45	30·43	nearly 3·50	as 1·00	to under 1·10	47·4	about 0·75
5	89·11	19·27	just over 2·00	as 1·00	to about 2·20	65·8	about 1·18
6	92·17	19·56	about 1·50	as 1·00	to over 1·75	46·7	about 0·96

The differences were seen to be considerable, and he should take No. 2 results to be approximately accurate, for both the marginal allowance and difference between slow- and quick-speed powers required in fairly normal work.

As regarded the excessive wire-drawing of the steam at No. 1 [redacted]

No. 2 plant had slide-valves, not badly suited on the admission side; but it would evidently be improved by removal of some exhaust cover on the inside, in order to reduce back-pressure and increase the efficiency. No. 3 plant also seemed to need some improvement on the exhaust side, and a slight increase of steam lead also. It would be of interest to test No. 4 plant at fairly high speeds, to see what increase of back-pressure would arise; but until full work on these engines was required it was hardly probable that they would be run specially for testing. No. 5 plant was certainly in a bad form, even if the diagrams given were a fair average, and should have a thorough readjustment before the separate cut-off was put in operation.

No. 6 plant showed very clearly the advantage accruing from the use of the cut-off gear from a fairly early part of the run, but would not give a good exhaust-line without cut-off. With regard to the advantage in exhaust with slide-valves over the double-beat Cornish valve, it was needed only to follow the extra twists and turns of the steam through the latter type of valve to see that the more direct passages of the former were an advantage when both were made the best of in design and areas of opening.

The most important consideration for securing economy with the modern winding-engine was to do the work with as great a range of expansion and as low a terminal pressure as was possible and consistent with the work, and to bring the cut-off into action as early as was practicable. There was no difficulty in arranging the cut-off to be in operation not later than the third revolution from the start, when all was properly designed and proportioned. A form of tabulated return was used by the writer for recording comparative results for ready reference and comparison, which gave the following particulars:—(1) engine, description; (2) running gear; (3) work done; (4) average gross pressure; (5) average effective pressure; (6) back-pressures and compression; (7) terminal pressure; (8) marks on diagrams; (9) proportions, terminals to effective; (10) cut-off points; and (11) remarks; No. 9 being the most important of the series.

Mr. W. C. MOUNTAIN (Newcastle-upon-Tyne) wrote that he had read Mr. Thacker's paper with great interest, and he considered that the Institution was greatly indebted to the author for the very careful way in which he had tabulated his

results, and also for the mathematical formulæ, which would be of considerable interest and value to designers.

The question of steam winding *versus* electric winding for main shafts and for heavy duty was a subject which had been, and was still, of great interest to mining engineers, and in which he (Mr. Mountain) personally took great interest, having contributed several papers thereon.* His object in writing these papers had been first of all to explain the various systems of electric winding, and, secondly, to find out, if possible, what the commercial prospects were.

The author showed some results taken from winding-engines, but he (Mr. Mountain) could only imagine that these engines were not quite up to date, as the consumption of steam per shaft-horsepower, that was, the actual horsepower in the shaft raising coal, did not compare at all with the results attained by Mr. Behr in South Africa with a Fraser & Chalmers twin-tandem compound condensing engine, and also at Sherwood colliery with a Fraser & Chalmers cross-compound engine. In the first case, the consumption of steam was between 25 and 26 pounds per shaft horsepower, and in the second case about 33 pounds. These figures were equal to anything that had been done, or to any claim which had been made, so far as he knew, by the advocates of electric winding.

There was no doubt that for heavy winding (and by this he meant a plant capable of dealing with an output of, say, not less

[redacted]

some extent, but it was quite possible to compare the two systems on the same depth.

So far as he could see, the cost of an electrical winding-gear for a given duty, complete with its motor, switch-gear, etc., would be nearly twice the value of a good modern steam winding-engine, and if the generating plant were to be added, the cost would then be about three times as much.

It should be borne in mind, that, for heavy winding, some kind of balancer arrangement, such as the Ilgner system, must be adopted, otherwise the very heavy demand for acceleration would involve a very large generating plant either at the colliery or on the premises of the suppliers of current. The following might be taken as the actual loss in a balancing arrangement of the flywheel type between the indicated horsepower of the engine and the actual horsepower on the shaft of the winding-gear:—Loss in engine, 10 per cent.; in generator, 6 per cent.; in cables, 3 per cent.; in balancer and motor, 10 per cent.; in generator, 8 per cent; and in winder and motors, 7 per cent. The net efficiency would, therefore, be about 58 per cent., say 60 per cent., so that there would be a loss of 40 per cent. in transformation, which would have to be allowed for. It followed therefore that although one might have an exceedingly high-class steam-engine for driving the main generator, by the time the power was delivered to the winder-shaft there was a loss of 40 per cent., or an increase in steam consumption of equal amount; and this was the principal reason why electric winding took nearly as much steam, if not quite as much, as a high-class steam winding-engine with the drums on the shaft.

He (Mr. Mountain) hoped that it would be clearly understood from the above remarks that he was by no means an opponent of electric winding in suitable positions. He believed that there were many places where electric winding could be used with advantage, such as at collieries where a cheap supply of current from a supply company could be obtained, or where current could be produced by waste gases. There was also a large demand for smaller winding-gears for small collieries and for staple-winding, and where the gears were of such a size that the current could be taken direct from the supply company's mains without difficulty. In such cases, with the increased economy, they were likely to be strong competitors of steam winding.

Mr. Gerald H. J. Hooghwinkel (London) wrote that Mr. Thacker deserved the thanks of all scientifically trained mechanical engineers for his careful methods of obtaining comparable results for winding-engine tests. This class of test had been most conspicuous by its absence, even at well-equipped mines and collieries. Only quite recently at the No. 1 shaft of the Village Deep mine in South Africa some very interesting results were obtained from a twin-tandem compound-condensing winding-engine by Messrs. Laschinger and Behr*, to which he (Mr. Hooghwinkel) would refer later.

He quite agreed with the writer that "The winding-engine of a mine, owing to the intermittent character of its work, and the variation of power from zero to maximum within a short period of time, presents difficulties in the economical utilization of steam, and in the accurate recording of the results obtained."† This statement was in itself an entire vindication of the claims made for electric winding on both points.

As he (Mr. Hooghwinkel) had been responsible for the design of most of the earlier electric winding-engines, and also the very latest and the only one, at present, winding coal in this country (at the Great Western collieries, Pontypridd), he would only deal with the results obtained with these engines and compare them with the excellent results obtained by Mr. Thacker. Incidentally, Mr. Thacker pointed out at once one of the reasons for the better results which should be obtained [redacted]

pared tests at the Zollern colliery and at the De Wendel collieries, particulars of which were published in the technical press.* Mr. Thacker, in the introduction to his paper, however, threw some doubt on these results and on the manner in which they were obtained. The tests on an electric winding-engine plant were, of course, far simpler than on a steam plant. The instruments gave a continuous record of the energy, power, current, etc., taken from the power-station, which records left no room for discussion. The writer hoped shortly to be in a position to publish figures obtained with the electric winding-engine at the Great Western colliery, Pontypridd; but preliminary tests had shown already that the power-consumption was well below the figures guaranteed by the makers. Taking these guaranteed figures as correct for the moment, and also referring to those obtained abroad, it would be interesting to compare them with Mr. Thacker's results. Any steam-consumption ought to be based upon the useful horsepower in the shaft for a period of at least 24 hours. The yearly figures, however, would give a more correct showing. The points especially referred to were: (1) mechanical efficiency and conversion losses; and (2) price.

The figure under (1) was given as 85 per cent. between input motor and useful horsepower in the shaft. The combined efficiency, or ratio between the useful horsepower on the rope and the units at the balancer terminals, was about 60 per cent., which was, of course, less than with a steam-engine plant, if the latter were taken during one wind, but better if the steam winder results were taken over 24 hours.

The mere percentage efficiency, however, told them nothing, just as in a comparison between a steam railroad or tramway and an electric system. Besides, the winding-plants compared in these remarks were all Ilgner or equal systems, which were not so efficient in themselves, but introduced greater efficiency in the power-station, both in steam-consumption and first-cost. It must not be forgotten, however, that there were several systems of electric driving where the overall mechanical efficiency was fully up to the direct steam drive, so far as the winding-plant was concerned.

What was of greater concern was, how many pounds of

* *Glückauf*, 1905, vol. xli., page 781.

steam and horsepower-hours were required to wind a certain quantity of coal, of miners' rubbish, and timber in, say, 24 hours, and what was the first-cost of the plant in each case, taking wages as being the same. The figures, which he (Mr. Hooghwinkel) proposed to put forward were from collieries where the conditions of the load were not so very different. He would take Mr. Thacker's figures in connection with test No. 5, this being one of the most modern plants for which steam-consumption figures were available. While it was quite correct to compare the most up-to-date steam winding-plant with electric winding-plant, so far as the steam-consumption was concerned, this should also be considered when the first-cost was being discussed. A modern compound condensing steam-winder with all modern improvements was not very much cheaper than an electric winder, and in many cases the cost was about the same.

Data.	Electric Winding-plant.		Steam Winding-plant.	
	Great Western Collieries Test.	Zollern Collieries Test.	Mr. Thacker's Test No. 5.	Village Deep Mine Test.
Depth of wind, in feet	1,110	1,000	1,659	2,290
Net load raised, in pounds ...	5,600	10,000	7,076	7,571
Running time, per cent.	—	—	—	65
Mean time of wind, in seconds ...	51·5	104*	48·3	79·0
Maximum rope speed, in feet per second	46	35*	65·8	37·6
Mean rope speed during wind, in feet per second	30	30*	24·3	29·0

[redacted]

With regard to the expense, the Zollern plant cost £10,000, and was designed for raising 2,000 tons from a depth of 1,500 feet in 8 hours, or 250 tons per hour. Mr. Thacker would put the cost of the steam winding-plant (non-condensing) at £2,500 per 100 tons, or £6,250 for 250 tons. The difference, even at this price (the Zollern was the first plant of its kind, and was therefore very expensive), was only 60 per cent. (not 200 per cent. as alleged), and would be made good in a very few years by the saving in coal alone. The winding-engine at the Great Western collieries cost £7,250, corresponding to a modern steam-plant at £4,400 on Mr. Thacker's figures. On accredited tests it might, therefore, be claimed for electric winding that the economy in coal alone would justify an even much larger increase in capital cost. The difference in favour of the steam-plant, however, varied considerably, and was tending to disappear altogether.

Mr. S. L. Thacker (Walsall), replying to the discussion, said that the Kœpe winding-pulley of No. 4 plant, referred to by the President, was built upon the existing cylindrical drum, there being consequently no reduction in the weight upon the shaft journals. As pointed out in the paper, however, the 4·1 per cent. required to equal the friction moment was not obtained under working conditions, but with steam shut off; the pressure upon the engines generally, upon the slides, and so forth, would be increased with steam admitted to the cylinders; but the test was of value as being a confirmation of the mechanical efficiencies obtained, and as showing that the loss due to mechanical friction in a steam winding-plant was considerably smaller than had been supposed.

The 32 per cent. loss of energy referred to was not obtained on No. 4 but on No. 5 plant. On reference to Table XVII., Appendix III., it would be seen that it was accounted for by deducting the effective work during the retardation period from the total kinetic energy and adding to the difference the amount of the friction co-efficient of the surplus energy. This large amount of wasted energy was quite independent of losses in the cylinders; it was a purely kinetic loss, the significance of which had been fully discussed in Section VI. (*c*).

As to the advantages or otherwise of a heavier balance-rope, it would be seen that its adoption in the case of No. 4 plant

had resulted in an increased efficiency, the kinetic loss being only 7·54 per cent. (Table A). As a general principle, he was of the opinion that a balance-rope was of the greatest service where a low ratio of paying load to total mass obtained, but in deep shafts with heavy ropes the increased weight on the rope-socket became an important consideration.

A case had recently been brought to his notice where 700 tons had to be raised in 8 hours from a depth of 1,650 feet, but, owing to the small size of tubs, the net load per wind was limited to 33 hundredweights. Three well-known makers of winding-engines had respectively specified for this work:—A pair of engines; cylinders, 22 inches diameter by 4 feet stroke, with a drum 12 feet diameter, at 120 pounds steam pressure; cylinders, 25 inches diameter by 5 feet stroke, with a drum 15 feet diameter, at 100 pounds steam pressure; and cylinders 30 inches diameter by 6 feet stroke, with a drum 18 feet diameter, at 100 pounds steam pressure.

He had gone through the figures and found that the 25-inch engines could only perform the work in the required time with a maximum rope-speed of 68 feet per second and a minimum kinetic loss of 23 per cent. By the adoption of a balance-rope to overbalance the weight of the winding-rope, the maximum rope-speed could be reduced to 58 feet per second and the kinetic loss reduced to about 5 per cent.

Mr. Hodges was evidently an advocate of plenty of reserve [redacted]

gear was such that it could not be operated at the speed attained, owing to the excessive noise; if the net load were increased, and the maximum velocity thereby reduced, each run would be made at a greater kinetic efficiency, and the expansion-gear could then probably be put in operation.

Mr. Turner's remarks were essentially practical, and his reference to the area of steam-ports and valve-opening was illustrated by the case of No. 1 plant, already referred to in the paper.* In reference to the economy resulting from automatic expansion-gear, Mr. Turner stated that he had met with instances of a resulting saving in steam of from 40 to 50 per cent. He (the author) was disposed to think that the economy attained was not always entirely due to improved steam distribution; it might in some cases be partly accounted for by the alteration in the acceleration-curve, with the result that the wind was performed with a lower maximum velocity, and consequently a less kinetic loss. That was a point which entered into the question of the economy of expansion-gear.

He presumed that Mr. Turner's remarks, as to the advisability in some cases of sacrificing efficiency to output, referred to instances where some additional duty might be required from existing plants. Mr. Turner would not traverse the author's contention that a new plant should be designed to raise the maximum output at the highest possible kinetic efficiency for the conditions.

Mr. Woodworth appeared to be in agreement with the author on general principles, but took exception to the results obtained on No. 1 plant, and had attempted to compare the results of the slow-speed tests by tabulating the margin of steam-pressure per square inch required to balance the frictional resistance. That was obviously an erroneous method of comparison, as the pressure per square inch on the piston to overcome friction would vary with the load and the size of cylinder, being less for a large engine than for a small one.

Mr. Woodworth was also wrong in supposing that the water had been a source of error in the slow-speed diagrams of No. 1 plant. Reference to figs. 6 and 7 (plate xxiii.) would show that the water in the connecting-pipes only gave trouble

* *Trans. Inst. M. E.*, 1908, vol. xxxv., page 607.

at full-speed, and that the slow-speed diagrams were entirely free from its influence. The fourth column of Mr. Woodworth's table, giving the ratio between the slow- and quick-speed powers, was unintelligible. He appeared to have taken the ratio between the mean effective steam-pressures as representing the proportion between the work performed under the slow- and full-speed tests, overlooking the fact that the number of revolutions under steam was not the same under the two conditions of winding.

Mr. Woodworth was more fully acquainted with the mechanical details of No. 1 plant than was the author, and he noted Mr. Woodworth's remarks upon the re-adjustment of the valve-gear which had resulted in less back-pressure and a reduction in the time of winding. He would, however, suggest that a more economical and satisfactory adjustment would have been to reduce the speed of winding by increasing the net load per wind, as set out in the calculations upon this plant in Section VIII.* It would then have been practicable to use an automatic expansion-gear.

The points raised by Mr. Mountain and Mr. Hooghwinkel might be considered together, as being the opinions of two electrical experts from different points of view. He was rather in agreement with Mr. Mountain than with Mr. Hooghwinkel. Both gentlemen had confirmed his own opinion as to the low overall mechanical efficiency of a balancer system; Mr. Moun-

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Referring again to the steam-consumption tests on Nos. 2 and 5 plants (Tables XIX. and XX., Appendix IV.), it would be noted that the consumption per indicated horsepower-hour was 87·9 pounds for No. 2 plant and 77·1 pounds for No. 5 plant, and on the mechanical horsepower 100·1 and 86·5 pounds respectively, while per effective horsepower-hour the figures were 105·4 and 127·1 pounds respectively, leading to the erroneous conclusion, on that basis, that the engine of No. 2 plant was the more economical in steam-consumption.

Further, he could not accept the view that a test should extend over 24 hours, as the proportionate time of winding would then materially qualify the results. An engine running 16 hours out of the 24 would obviously have an advantage over one winding 8 hours only, whether electrical or otherwise. Stand-by losses, both for electrical and steam winding-plants, should be separately determined.

He would emphatically insist that to be of any true comparative value, a test should include the determination of the indicated, mechanical, and effective horsepowers: the mechanical horsepower-hours at the winder shaft being the basis to which the steam-consumption should be referred when comparing the performance of individual engines. He hoped that Mr. Hooghwinkel would give further consideration to the matter before publishing the detailed results obtained with the electric winder at the Great Western collieries, which could not fail to be of great interest.

The tests upon the winding engines at the Village Deep mine,* South Africa, and at Sherwood colliery,† were carried out with great care, and, as Mr. Mountain had mentioned, the results were probably the best so far obtained for condensing and non-condensing winding-engines respectively. Unfortunately, however, they could not be properly compared, as the indicated horsepower and kinetic efficiency were not determined in the Sherwood test. The kinetic efficiency of the Village Deep plant worked out at 85·18 per cent., which, however, was wrongly stated in the published results as the value of the mechanical efficiency. The actual figures for the steam-consumption per

* *Proceedings of the South African Association of Engineers*, March 3rd, 1906.

† "Test of a Modern Winding-engine," by Mr. David A. Bremner, *The Engineer*, 1906, vol. cii., page 600.

effective horsepower-hour were 33·95 pounds for the Sherwood cross-compound engine and 25·55 pounds for the Village Deep twin-tandem compound engine; not 30·2 pounds, as stated in Mr. Hooghwinkel's table.

Mr. Hooghwinkel had elected to compare these results with the figure obtained by the author on No. 5 plant, namely, 127 pounds per effective horsepower-hour, a comparison which, for the reasons already stated, was of no value. On the indicated horsepower, the steam-consumption of the Village Deep engine was given in the paper by Mr. Behr at 21·76 pounds, and for No. 5 plant the figure was 77·1 pounds, a comparative result which one would expect to find when comparing a compound-condensing Corliss engine with a non-expansive, non-condensing engine with badly adjusted valve-gear.

As to costs, he was quite prepared to admit that electric winding-machinery would be reduced in price, but the figures given by Mr. Hooghwinkel were exclusive of the generating plant and its accessories, a proportionate amount of which should, of course, be debited to the cost of the winder when considering self-contained plants. Mr. Mountain was evidently of the author's opinion as to the relative costs.

He was much obliged for the complimentary manner in which his critics had dealt with the paper, and he hoped that the interesting points raised in the discussion had been answered to their satisfaction.

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large experience, and well able to take a personal interest in all matters coming before the Institution. As long as they had Presidents like Mr. Rhodes, he was quite sure that the Institution would prosper, no matter whether its headquarters were in the North of England or in London.

Mr. W. B. Wilson (Easington) said that he had pleasure in seconding the vote of thanks for the very genial and efficient manner in which the chair had been occupied during the last two days.

The resolution was carried by acclamation.

The President thanked the members for their kind vote.

The following notes record some of the features of interest seen by visitors to works, etc., which were, by kind permission of the owners, open for inspection during the course of the meeting on June 4th, 5th, and 6th, 1908:—

FRANCO-BRITISH EXHIBITION: MINING, METALLURGICAL, AND ENGINEERING SECTIONS.

The members were received in the Machinery Hall by Sir Hugh Bell, Bart., President of the Iron and Steel Institute and Chairman of the Iron and Steel section of the Exhibition; Mr. T. Hurry Riches, President of the Institution of Mechanical Engineers and Chairman of the Mechanical Engineering section; and Prof. H. Bauerman and Mr. Bennett H. Brough, members of the Iron and Steel sectional committee, these two last-named gentlemen acting as guides.

In the Mining section a notable feature was the display of the various coal-seams throughout Great Britain, supplemented by collections of the ores and minerals worked in the United Kingdom. The exhibits of fire-bricks of Indian magnesite, and of platinum and other rare metals, attracted great interest.

In the French Mining section, the interest of the visit to the collection, admirably illustrating the scientific aspects of French mining, was enhanced by the descriptions given by the French Commissioner (Mr. Dubruel).

The members inspected the collective exhibit illustrating the British Pig-iron Industry, which was housed in a pavilion of an ornate structure. The interior walls of the pavilion were [redacted]

A most extensive display by almost all the iron-masters and steel producers had been arranged, from the heavy steel forgings and castings to rolled plates of dimensions such as have never before been shown in any exhibition, including heavy guns and armour plates, both finished and in an unfinished state. An attractive display of wire ropes for colliery and other purposes was inspected with interest by the visitors.

Amongst the pumping machinery was exhibited the latest development of the steam-turbine, coupled direct to electric generators, this plant of 2,000 horsepower being used to supplement the electric current for illuminating the Exhibition and grounds. These turbines were driven by water-tube boilers of the most modern type. A vertical gas-engine of 1,000 horsepower, coupled to an electric generator, also contributed its output to the illumination of the Exhibition, the gas being supplied by a Mond gas-producing plant of 2,000 horsepower.

The Electrical department, organized by the combined electric-supply companies of London, illustrated the employment of electricity for domestic and commercial purposes, and the general advance that had been made in its use.

In the Gas Engineering group, the various uses to which gas was being put in the home, the factory, and the department of public lighting, were shown. In this section were installed the compressors used for lighting the upper part of the grounds of the Exhibition with high-pressure gas.

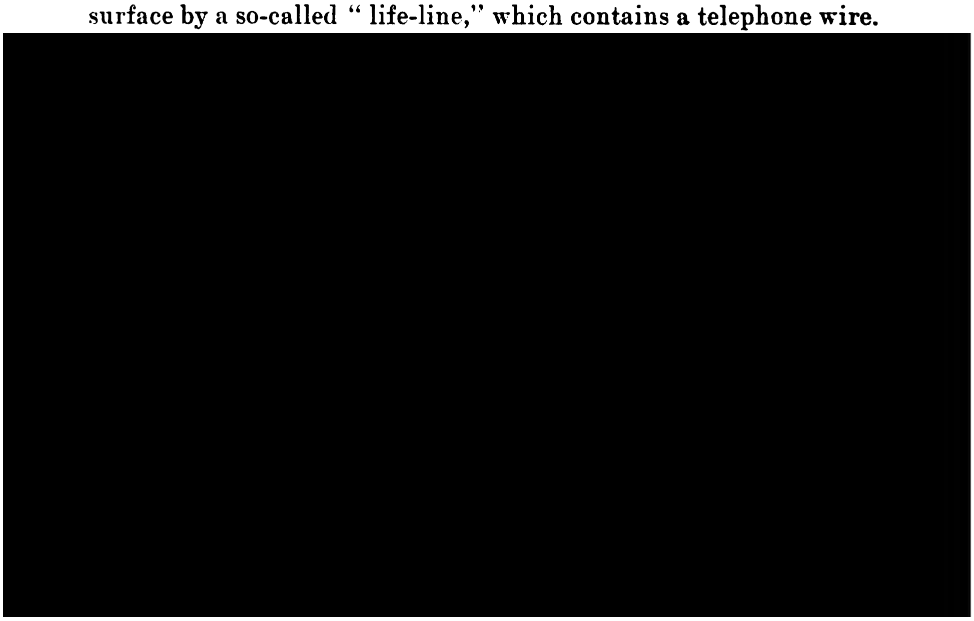
Other points of interest in the Machinery section were the extensive collection of cotton, woollen, and weaving machinery from Lancashire; automatic machinery for working iron, steel, and other metals; a printing press used for the printing of the daily programme; and mechanical devices for labour-saving employed in various branches of engineering.

DEMONSTRATION OF DIVING-APPARATUS, ETC., AT THE WORKS OF MESSRS. SIEBE, GORMAN & COMPANY, LIMITED, LAMBETH, LONDON, S.E.

The diving demonstration was given in a large experimental tank; and the use of the following apparatus was shown:—

I.—The Diving-apparatus used in the Royal Navy, with the most recent improvements.

The ordinary English diving-dress, devised in its original form by Siebe early last century, consists of a copper helmet screwed to a metal corselet, the latter being clamped water-tight to a stout waterproof dress covering the whole body except the hands, which project through elastic cuffs. Air is supplied to the diver through a non-return valve at the back of the helmet from a flexible pipe connected with an air-pump. The air escapes through an adjustable spring valve at the side of the helmet. The arrangement is thus such that the pressure of the air in the helmet is always equal to, or slightly greater than, the water-pressure at the outlet-valve. For every 34 feet of fresh water (33 feet of sea-water), the pressure increases by 1 atmosphere, or nearly 15 pounds per square inch. At a depth of 34 feet, the diver is therefore breathing air at an excess pressure of 1 atmosphere, or an absolute pressure of 2 atmospheres. It is absolutely necessary that he should breathe compressed air: otherwise his breathing would be instantly stopped, and blood would pour from his mouth and nose. In order to enable the driver to sink and stand firmly on the bottom, the dress is weighted with 40-pound leaden weights, back and front, and 16 pounds of lead on each boot—about 112 pounds of lead in all. Besides the air-pipe connection, the diver is connected with the surface by a so-called "life-line," which contains a telephone wire.



It would require only a few inches of additional adverse pressure to practically stop the breathing altogether. One of the first things that a diver has to learn is to avoid this adverse pressure by regulating the pressure of the spring on the outlet-valve, so that the breathing is always quite free. The spring on the valve at the same time regulates the amount of air in the dress, and therefore the buoyancy of the diver. A practised diver can thus slip easily, and without exertion, up or down the rope. The breathing is, of course, easiest when the dress is full of air down to the level of the abdomen; but, when this is so, the diver is in danger of being "blown up." It will also be readily understood that a horizontal, or nearly horizontal position is the easiest one for a diver's breathing; and divers commonly work crawling along the ground. In this position it may easily happen that too much air gets into the dress. If this air is allowed to get into the legs of the dress, the diver is capsized and blown helplessly to the surface: or he may be caught by a rope or other obstruction, and hung up in a helpless position with his legs upwards, the excess of air being unable to escape at the valve since it is downwards. To avoid this risk there is now an arrangement for lacing up the legs. With the legs laced up, the head always comes uppermost if the diver tends to float upwards: hence the excess of air escapes by the valve.

II.—New Self-contained Diving-apparatus.

For most of the diving work likely to be needed in mines, the ordinary diving-apparatus would probably be quite suitable. This apparatus is extremely efficient and safe, and inspires great confidence. In some cases, however, the length of pipe needed might cause much difficulty. If, for instance, it were required to go down a shaft under water, and then along a piece of submerged road, there would be great difficulty with the pipe. For this purpose a self-contained diving-apparatus, without any air-pipe, would be needed. As is well known, an apparatus of this kind was devised nearly thirty years ago by Mr. Fleuss, and used with signal success in saving the workings of the Severn Tunnel when they were accidentally flooded by an irruption of water.

There are, however, certain difficulties and dangers connected with the use of the original Fleuss apparatus. To overcome these disadvantages, a new self-contained apparatus has just been de-

signed. The supply of oxygen is automatic, as in the mine-rescue apparatus; and the dress completely envelopes the diver, as with the ordinary diving-apparatus. Instead of pure oxygen, a mixture of pure oxygen and air is supplied to the diver, the percentage of each varying with the depth of water. By this means the danger of oxygen-poisoning at ordinary depths is avoided. Much more of this mixture is needed than if pure oxygen were supplied, but the extra weight of steel cylinders is of little importance, as the diver must be artificially weighted in any case, to enable him to sink.

The apparatus was publicly shown for the first time at this demonstration.

III.—THE HALL-REES LIGHT DIVING-DRESS AND SMOKE-HELMET.

This apparatus was recently designed by Captain Hall and Staff-Surgeon Rees of the Royal Navy, with the particular object of furnishing a means of escape from a submerged submarine. It can be used for diving to small depths for short periods, not exceeding forty-five minutes. It can also be used as a smoke-helmet. It is very light, and can be put on without assistance in thirty seconds. It consists of a helmet, sloped away to fit the shoulders, and continued into a short waterproof jacket. In front of this jacket is a pocket containing an "oxylithe"-purifier and oxygen-generator, as in the Pneumatogen rescue-apparatus. The diver breathes by a tube through this purifier, which is connected by another tube with the air-space in the helmet. The [redacted]

wall Tunnel, Ordnance Wharf, East Greenwich, the latter comprising one of the most complete and modern tar-distilling plants in the kingdom.

The tar-works cover an area of 7½ acres, and have an extensive frontage to the river, with a jetty to which ships up to 2,500 tons can come, for taking cargoes of pitch and of the numerous other products that are made. The works were originally owned by Messrs. Forbes, Abbott, & Lennard, Limited, and were acquired by the Gas Company in 1903. Now all the tar made at the Company's gas-manufacturing stations is dealt with at Ordnance Wharf. The tar from the East Greenwich works is pumped to the tar-works through a 9-inch cast-iron pipe, while that from Old Kent Road, Vauxhall, Bankside, Rotherhithe, and West Greenwich is brought in tank-barges, the contents of which are pumped first into settling-tanks and then into a store-tank. The store-tank is a large circular underground pit built in concrete, and is capable of holding 1,300,000 gallons of tar. This large storage accommodation enables the distilling plant to be worked continuously all the year round; and every year about 11,000,000 gallons of tar are dealt with. There are three distinct sets of distilling plant, one of them being the first continuous plant built under Mr. F. Lennard's patent. The other two are on the same system, with, as is to be expected, many improvements in detail. One still has a capacity of 24,000 gallons of tar in twenty-four hours, another can get through 14,000 gallons, while the third, of 16,000 gallons capacity, is used as a stand-by. In the stills and associated condensers the tar is continuously, and almost automatically, separated into four fractions—pitch, anthracene oil, creosote oil, and light oils. The oils are afterwards fractionated in separate stills, producing a large number of products. The extent to which this further fractionating is carried at any particular time is governed largely by the condition of the market for the various products. For instance, at the present time the market does not offer any great inducement for the production of anthracene; therefore only sufficient anthracene is distilled out of the tar to make the pitch hard enough to be marketable. The oil obtained from the anthracene is used for making grease, preserving timber, and as fuel in furnaces. The creosote oils are first treated for the recovery of carbolic and cresylic acids. After

this treatment, the oil is sometimes run off and sold for creosoting purposes, and at other times it is further treated for the recovery of naphthalene crystals (fig. 1). The naphtha and light oils are fractionated into, among other things, benzol, toluol, and solvent naphtha. The Company are now developing a considerable business in the supply of benzol for motor-car purposes. All their own cars are run on this fuel, and they also supply many outside customers, the benzol being put up in neat hermetically-sealed cans.

Externally the tar-still is a large rectangular brick structure, heated by a number of furnaces fired with creosote oil, or by crude tar burned in the Field-and-Kirby patent tar-

[redacted]

heated to drive off all the water and most of the naphtha; this hot tar is run into underground tanks, and from them forced into the coil in the still by means of a pump, with the assistance of air pressure. In the pitch-column or scrubber the pitch falls down, and, after being scrubbed by steam, passes through a steam-jacketed pipe into closed tank-coolers, and ultimately into the pitch-bays, which have a total capacity of about 10,000 tons. In the first condenser the anthracene oil is brought down, in the second the creosote oil, and in the last the light oils. All the operations are regulated by thermometers placed at appropriate points, and the flow of tar into the condensers and into the still is controlled by dial cocks.

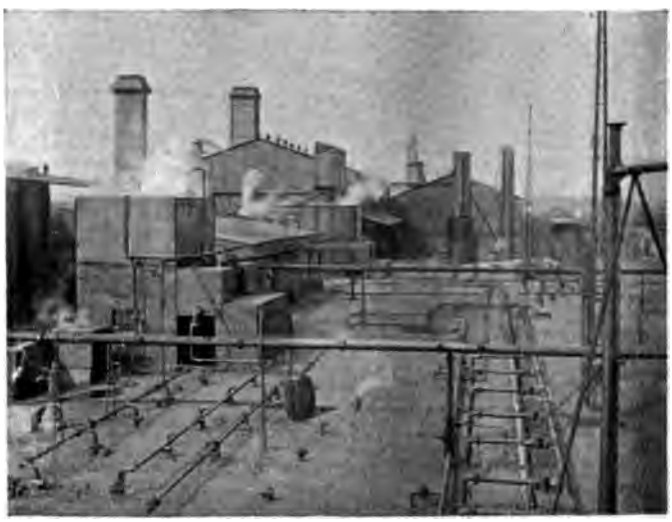


FIG. 2.—PIPE CONNECTIONS TO UNDERGROUND STORAGE-TANKS.

The method of dealing with pitch at these works is very efficient, the whole being aboveground. A large part of the plant employed in other operations is composed of underground tanks, the only indication of which to the eye is the long range of valved pipes stretching across the yard (fig. 2).

The foundations of the site being poor, the piers for carrying the track of the pitch transporter are built on piles. The bays are arranged in a line at right-angles to the river, and the railway-line is stretched across them. Upon this there runs a

Temperley travelling tower transporter (fig. 3). By means of this, pitch can be taken from any bay in the line, and transported to the side of the river, skips capable of containing one ton being employed for the purpose. The tower transporter transfers the skip to a weighing-machine, and from the weighing machine the skip is taken by a Temperley bridge transporter, travelling on rails on the wharf side, and by it transferred to the hold of the ship, where the skip is self-tipped. With these appliances some 30 tons of pitch can be loaded into a ship in an hour.

[redacted]

when the tar-fire is once started, with the aid of a little wood, no further trouble is experienced. Mr. Field, the joint inventor with Mr. A. Kirby of the new method of firing, estimates that 1 ton of tar is equivalent, as fuel, to 1½ tons of best Welsh steam-coal. The tar burned at Ordnance Wharf is the crude tar as it comes from the gasworks, containing about 3 per cent. of water.

In addition to the above-described plant, there are well-equipped laboratories; an engineering shop, where practically all work except casting is done; a cooperage, where the casks are repaired; and a small electric-light plant for lighting part of the works. In the benzol house, which is the danger spot, the electric lights are enclosed in double globes. There are also a fire-engine station and fire-extinguishing appliances. As an additional precaution against fire, stores of sand are kept at convenient points. Happily, as with the continuous plant practically everything is enclosed, there is seldom any call for the firemen.

MANCHESTER GEOLOGICAL AND MINING SOCIETY.

GENERAL MEETING,

HELD IN THE ROOMS OF THE SOCIETY, QUEEN'S CHAMBERS,
5, JOHN DALTON STREET, MANCHESTER,
JUNE 16TH, 1908.

MR. JOHN ASHWORTH, PRESIDENT, IN THE CHAIR.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. JOHN WILLIAM JOBLING, Mining Engineer, Clifton Colliery, Burnley.

Mr. ARTHUR MOORE LAMB, Mining Engineer, Eskdale, Birkdale, near Southport.

Mr. JOSEPH CRESSWELL ROSCAMP, H.M. Assistant Inspector of Mines, Prestwich, Manchester.

Mr. FRANK G. L. SAINT, Colliery Manager, Glen Tarn, Hindley Green, near Wigan.

[redacted]

THE MODE OF OCCURRENCE OF MANGANITE IN THE MANGANESE-ORE DEPOSITS OF THE SANDUR STATE, BELLARY, MADRAS, INDIA.

By A. GHOSE, F.C.S.

The deposits of manganese-ore found by the writer in the hill-ranges of the Sandur State, Madras Presidency, India, are not only remarkable for the extraordinary development of the is general in the series of deposits, and their mode of occurrence of some minerals of manganese in finely crystallized forms. Of these, manganite, which is comparatively rare in other parts of India, is so frequently met with in the manganese-ore deposits situated on the Sandur Hills, that no deposit is known in that area where it has not been observed. Although the crystals of manganite are not always found in the state of development which is noticeable in some specimens, yet their distribution is general in the series of deposits, and their mode of occurrence is identical with rare exceptions. They are invariably found lining cavities or infilling narrow fissures formed in the beds of the ore, either consisting of psilomelane or of psilomelane and wad, and more rarely of an intimate mixture of psilomelane and braunite. A typical specimen of manganite from the Ramandrug mine, which was the first to be identified, has been described by Mr. L. L. Fermor.*

The cavities assume various irregular shapes, and are more frequently angular and very rarely ellipsoidal. They vary in size from the fraction of an inch to a few inches across. Their presence inside the ore-mass cannot always be detected by examination of the outward appearance of the ore, and geodes lined with crystals have been found inside solid-looking ore, although their occurrence is more frequent in ore which shows an apparently brecciated structure. Sometimes the exterior surface of the ore-mass containing the geodal cavities shows a

* *Records of the Geological Survey of India*, 1906, vol. xxxiii., pages 229-232.

peculiar "pitted" structure, resembling "thumb-marks." These depressions were caused by the removal of crusts concentrically deposited in hollows. The drusy cavities, in rare instances, have been found immediately on fracture to contain minute traces of a liquid which has hitherto afforded no opportunity for an examination. Where the concentric lining of the cavity consists of compact psilomelane without any capillary fissures, the acicular crystals of manganite are found to retain a shimmering brilliancy almost approaching irridescence. On the other

[redacted]

of suspended impurities. Delicate needle-like prismatic crystals of manganite grouped in bundles, and sometimes disposed perpendicularly to the walls of the cavity, showing brush-like aggregations and more frequently exhibiting radiated fibrous structure, project towards the central druse. The compact psilomelane and the crystals of manganite are symmetrical in arrangement. Pseudomorphous crystals of pyrolusite exactly reproducing the acicular form of manganite are very frequently found lining the cavities, and are probably the alteration-product of the dehydration of original crystals of manganite. It is probable that in many cases the crystals of manganite have undergone alteration, and are no longer true manganite. In some geodes and fissures alternate deposition of compact psilomelane and of a crystalline mineral with silvery lustre (probably hollandite)* has been noticed. The layer of this hitherto unidentified mineral is covered by another crust of compact psilomelane, from the surface of which crystals of manganite spring up. This symmetric succession of minerals is an evidence of cycles of precipitation, and the oldest crust always rests directly on the primary ore.

Of the various hypotheses propounded from time to time to account for the origin of the manganese ore-deposits of the Sandur State, two theories appear to be based on comparatively sound deductions. One of these advocates a contemporaneous sedimentary origin, and the other maintains that the deposits are essentially the result of replacement of the original country rock by mineralizing solutions. On the assumption that the ore-deposits are of contemporaneous origin with the enclosing Dharwar rocks, it is admissible to suppose that the cavities were of later origin, and were formed and filled up subsequent to the folding and uplifting of the ore-beds. Whether the enlargement of the fissures and the formation of the cavities, the precipitation of psilomelane, and the crystallization of manganite, were the resultants of uprising magmatic waters derived from igneous intrusions is problematical. The presence of magnetite, mangan-magnetite, and specularite in the ore appears to lend some support to such a theory. On the other hand, that the cavities were

* A new manganese-mineral, discovered by Mr. L. L. Fermor, and described by him in his paper on "Manganese in India," *Transactions of the Mining and Geological Institute of India*, 1906, vol. i., pages 76-77.

dissolution resulted in the formation of narrow open spaces and cavities, which mark periods of cessation or interruption of the process of deposition. These spaces of dissolution subsequently served as loci for the deposition of compact psilomelane and manganite.

Fig. 1 is a view of the Ramandrug mine, where geodes lined with manganite are abundant, showing the main working and ore-stacks at a distance. The protruding mass cresting the hill on the left of the view is entirely composed of manganese-ore. The light railway conveys the ore to the loading station of the

[redacted]

Fig. 3 is a portion of a geode of psilomelane from the Ramandrug deposit, containing fine, fibrous, divergent crystals of manganite.

On the motion of Mr. J. S. Burrows (Atherton), the thanks of the meeting were tendered to Mr. Ghose for his paper, the motion being seconded by the Honorary Secretary (Mr. Sydney A. Smith), who said that the paper was a most interesting one, dealing, as it did, with one of the less common metals.

The following paper, by Mr. Leonard R. Fletcher, was read, on "The Patent Keps under the Cages at Chanters Pit, Atherton Collieries": —

THE PATENT KEPS UNDER THE CAGES AT CHANTERS PIT, ATHERTON COLLIERIES.

By LEONARD R. FLETCHER.

For many years the ordinary fang-keps, with which all colliery-managers and engineers are more or less familiar, were in use at Chanters No. 1 pit. A few years ago, however, the attention of the management was called to the various forms of improved keps on the market; and, after consideration, it was decided to give a trial at this pit to the Beiens mechanical kep-arrangement. The chief advantages claimed for these keps are:—

(1) The allowing of the withdrawal of the keps from under the cage with the full load of the cage upon them, so that the engineman has no need to reverse his engines for banking purposes.

(2) A consequent saving of labour to the engineman in manipulating the winding-engines.

(3) A consequent saving of time and steam.

(4) A consequent reduction of wear-and-tear on the winding-

[redacted]

by the banksman. The connexion of this twin-lever with the supporting bar, *A*, is effected through a pin, *a*, which bears a roller, *b*, and is caused to move in a circular slot, *c*, in the supporting bar, whereby this bar executes a backward or forward movement.

The winding-cage rests on a level surface on the supporting bar, *A*. The pressure exerted by the winding-cage on the bar is taken by the surfaces of the casing at the points marked *d* and *e* (fig. 3). Both of these surfaces form in the vertical elevation a part of the circumference of two concentric circles, and are so arranged that the pressure on the pin in this circular slot is reduced to a minimum.

The supporting bar, *A*, when withdrawn (fig. 3) executes not only a backward, but also a downward movement, on account of the concentric surfaces of the bar and the casing, *B*, whereby the winding-cage receives a slow downward movement.

In case it should happen that the supporting bar, *A*, should be pushed forward too soon, before the winding-cage has reached the proper height, the ascending cage will turn the supporting bar round the pin and push it out of the way, so that the ascending cage can pass freely through (fig. 3, *f*). After the cage has passed the bar, the latter again falls into its original position by reason of its own weight, and is ready for the cage to rest on (figs. 2 and 3, *A*).

For comparatively light loads these supporting bars are made with a broad flat surface, and the frame of the cage rests directly upon them; but for heavy loads these bars are made with a sloping face, and a counter-shoe with a corresponding face is riveted firmly on the underframe of the cage. At Chanters pit these bars have the flat face, but for special reasons a shoe with a flat face is riveted on the cage. The hand-lever works in a notched quadrant, and is easily manipulated by the banksman. The makers of these keps claim that they are more suitable than any others for heavy loads, and that they have already been made for loads of 27 tons, and are working quite satisfactorily.

Since these patent keps have been put in at Chanters No. 1 pit, three-deck cages have been substituted for the two-deck cages formerly in use, and the advantage gained by the use of these keps has been most pronounced. Apart from the saving of time, labour, and steam, there is, of course, less fear of

accidents from overwinding due to the engineman starting the wrong way. As soon as the cage is resting on the catches, the reversing lever can be moved over ready for the next winding, the keps being withdrawn from under each deck of the cage without any help from the engineman. Thus one source of accidents due to overwinding is minimized, and the winding-engineman is relieved of much unnecessary work and worry. Objection is sometimes raised to the catches from the mistaken theory that slack chain may be resting on the cage, which will suffer a severe shock and strain when these keps are withdrawn. As a matter of fact, this can never happen in actual practice, as the weight of the opposite cage-rope hanging in the pit will instantly take up any slack rope or chain that there may be when the top cage comes to rest upon the keps.

In conclusion, the author would say that this short paper is not written with the object of raising the question whether or not keps should be used under pit-cages when winding coal or men, but to bring before the members an ingenious and simple contrivance which has all the advantages and none of the disadvantages of the old form of fang-keps.

Mr. John Gerrard (H.M. Inspector of Mines, Worsley) proposed a vote of thanks to Mr. Leonard R. Fletcher for his admirable paper, which was seconded by Mr. W. Scott Barrett [redacted]

THE LEE SAFETY-APPLIANCE FOR CAGES.

By T. H. WORDSWORTH.

The following is a description of an appliance recently invented to prevent a cage from falling to the bottom of the shaft in the case of a winding-rope breaking where wire-rope conductors are in use.

The principle of the invention is a cam to grip the rope-conductors, actuated in the first instance by springs, and then by the weight of the cage. The chains which keep these springs out of action during the winding would also act as safety-chains in case of any of the four corner-chains breaking.

Figs. 1 and 2 (plate xxxiii.) are side and end elevations of a double-decked colliery cage fitted with the appliance. Figs. 3 and 4 are enlarged views of the gripping device.

Each side of the cage, *a*, is fitted with a vertical bar, *b*, the upper ends of the bars being connected together by a cross-stay, *c*, and to the cage suspension-chains, *d*, which in turn are secured to the winding-rope.

The bottom ends of each bar are secured to a bar, *e*, passing under the cage-bottom, *f*, and two or more coiled springs, *g*, *g*, are disposed between the bar, *e*, and the cage-bottom, *f*. At right angles to each vertical bar, *b*, is a horizontal bar, *h*, which slides freely in a vertical direction in suitable guides or bearings, *i*, connected to the cage, *a*. The guides, *i*, are shown more clearly in the end view (fig. 5, plate xxxiii.), and consist of two plates, *i*,*i*, spaced apart to receive the horizontal bar, *h*. The ends of the horizontal bars, *h*, are extended around and embrace the side-conductors or guide-ropes, *j*, of the cage, forming a trough for the guide-ropes. This is more clearly shown in the enlarged plan (fig. 4, plate xxxiii.). The side-bars, *b*, are formed with a bent portion, b^1, as shown in the side view in fig. 3, and pivoted to each vertical side-bar, *b*. At this point are a pair of angle-levers, *k*, the outer ends of which are also pivoted to the horizontal bars, *h*, at h^1, the cranked ends, k^1, of the levers, *k*, being disposed

within the trough. The levers, *k*, are loosely pivoted to brake-shoes, *m*, so formed in conjunction with the troughs on the ends of the horizontal bars, *h*, that as when the levers, *k*, are pulled downwards with the vertical bars, *b*, the levers, *k*, turn on their fulcra, and, by means of the brake-shoes, securely grip the conducting ropes, *j*.

The action of the apparatus is as follows;—When the cage is in use, the weight of the cage is transmitted through the middle suspension-chains to the vertical side-bars, *b*, which are raised, and thus compress the springs, *g*, *g*, interposed between the bottom cross-bar, *e*, and the cage-bottom, *f*. The angle-levers, *k*, are also lifted centrally, removing the brake-shoes, *m*, from contact with the guide-ropes, *j*, the cage running freely on the guide-ropes. In case of breakage of the winding-rope, the lifting strain on the vertical bars, *b*, will be released and, the compressed springs, *g*, will force the bars, *b*, downwards. The angle-levers are thus turned on their fulcra, as shown in dotted lines in fig. 1, (plate xxxiii.), and the break-shoes, *m*, brought into action to grip the guide-ropes, *j*, thus securely binding the horizontal bars, *h*, and the angle-levers, *k*, to the guide-ropes, and immediately arresting their descent.

The descending cage compresses the springs, *g*, until the whole weight of the cage, acting through *b*, is brought to bear upon the angle-levers, *k*, and exerts such a powerful gripping action upon the guide-ropes, *j*, that the fall of the cage is arrested.

[redacted]

portion of the tackle has given way, and allowed the cage to fall to the bottom of the shaft. In such a case this appliance would hold the cage, and prevent an overwind from developing into a serious accident.

An objection to catches of this nature has been that they come into operation when the cage is at rest on the keps, or at the bottom of the pit. In this arrangement, however, when the cage is at rest on the landing at the pit-bottom, the springs are kept compressed, so that the cams do not grip the conductor; and an amplification can be made which causes the springs to be compressed when the cage is at rest on the keps.

The following "Description of a New Patent Appliance for arresting the descent of Cages in Shafts, in the Event of the Winding-Rope Breaking," by Messrs. Joseph Hindley and John Stoney, was read by Mr. JOSEPH HINDLEY:—

DESCRIPTION OF A NEW PATENT APPLIANCE FOR ARRESTING THE DESCENT OF CAGES IN SHAFTS, IN THE EVENT OF THE WINDING-ROPE BREAKING.

By JOSEPH HINDLEY and JOHN STONEY.

The appliance has for its object the arresting of a cage in a mine-shaft in the event of the winding-rope breaking, or becoming detached from any cause; and is shown in detail in figs. 1 to 9 (plate xxxiv.). In the first place, if the rope breaks a considerable distance above the cap, the lower part of the rope must receive an acceleration downwards relative to the cage. The springs, *a* (fig. 1), have sufficient tension to pull the rope down even in an extreme case (that is, the longest length of rope), within a reasonable time.

The braking force is obtained by means of wedges and forked levers (one of each to each guide-rope). The wedge, *b* (fig. 8), moves in a suitable box, *c* (fig. 6), with the thin edge of the wedge uppermost. The brake is applicable to cases where two, three, or four guide-ropes are used, and can be applied to exist-

[redacted]

project beyond the guide-ropes, so that there is no liability of these parts coming into action through meeting any obstruction in the pit-shaft. The boxes (figs. 4, 5, and 6) are provided with guides or thimbles at both top and bottom, which are easily and cheaply renewed when worn.

The face of the wedge, *b* (fig. 8), and the corresponding part of the box is grooved in semi-circular form, so that there is no cutting, kinking, or alteration in the shape of guide-ropes.

Mr. George H. Winstanley (Manchester) said that it was very refreshing to find a safety-cage for which the inventor did not claim that it was capable of doing everything. Mr. Wordsworth had, for the inventor, frankly admitted a doubt as to the action of the Lee appliance in the case of a rope breaking with a descending cage. That it would act in the event of a rope breaking when the cage was ascending was obvious, and there were many such appliances that would act under these conditions. It was interesting to note the important circumstance in this particular appliance, that its use would not prevent the employment of "decking platforms." With regard to Messrs. Hindley and Stoney's appliance, it was pleasing to note that the inventors had recognized and taken into consideration what many inventors of safety-cages had refused absolutely to admit, namely, the existence of kinetic energy, which was a tremendous force to be reckoned with in the case of a heavy cage descending at a high speed. Messrs. Hindley and Stoney had apparently recognized the necessity of stopping the descending cage gradually, with a sort of braking effect, and avoiding anything like a sudden stop. Any attempt to stop suddenly a rapidly moving cage was simply courting disaster. He moved a vote of thanks to the three gentlemen.

Mr. H. Stanley Atherton (Bolton) seconded the motion, which was adopted.

Mr. George H. Winstanley asked whether Mr. Hindley or Mr. Stoney could explain what would happen in the case of commencing a winding where the acceleration of speed was very quick. One could conceive that there would be for a moment an apparent reduction in the weight of the descending

cage, due to acceleration. Would the springs then come into operation? He would like to be assured that this was not likely to happen. It was possible for the springs in some appliances to come into operation, on account of a temporary reduction in the weight of the cage.

Mr. JOHN STONEY (Manchester) said that they had made an indicator, and obtained diagrams from the same which showed the acceleration of the cage, and the tension on the winding-rope at any part of the pit-shaft. This appliance he exhibited to the members.

Mr. JOSEPH HINDLEY (Tyldesley) exhibited diagrams shewing the different effects produced by varied conditions, which demonstrated that the tension on a winding-rope varied from half the weight of the cage upwards. This gave a factor of safety of 4, if the tension of the springs be equivalent to one-eighth of the weight of the empty cage.

In reply to another question as to whether the greatest tension of the winding-rope had been found by this indicator, Mr. Hindley said that such information would be of no service to them in their work, but it was possible to get it easily by a slight alteration in the indicator. The catches had been tested up to a weight of 6 hundredweights. They had not been tried, as yet, under ordinary working conditions.

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Mr. HINDLEY replied that the rope falling down would be a gradual force applied to the cage; if it dropped on the chains (which it would do or miss the cage), it would drive the wedges tighter.

Mr. JOHN S. BURROWS said that he had known a rope coil itself so much round a cage that the rope had to be cut away in pieces. Would not 1,200 feet of rope falling on a suspended cage in the shaft upset the safety-arrangement.

Mr. HINDLEY replied that it could not possibly pull out the wedges; in fact, it would tighten them. They had taken into account the falling winding-rope in their calculations of the strengths of various parts.

APPENDICES.

I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

UNDERGROUND TEMPERATURES: VALUES OF THE GEOTHERMIC DEGREE.

Normale und anormale Werthe der geothermischen Tiefenstufe. By JOH. KÖNIGSBERGER. *Centralblatt für Mineralogie, Geologie und Paläontologie,* 1907, *pages* 673-679.

One of the objections advanced against the hypothesis of regular increase of temperature, concurrently with increased depths from the earth's surface, is based on the extreme irregularities observed in underground temperatures near the surface. Such irregularities are undeniable: at some localities (*e.g.*, Neuffen) there is a rise of 1 degree Fahrenheit for every 18 feet of depth, at others (*e.g.*, Chicago) the rise is 1 degree for every 128 feet of depth; and there are metalliferous mines where even a fall of temperature is locally noted with increasing depth. But these different values are not irregularly distributed, as some writers have thought; they can be grouped in well-defined categories dependent on geographical and geological factors, and this grouping is defensible by arguments drawn from physics and mathematics.

The author gives a series of tables embodying the known geothermic values in different localities classified as follows:—(1) localities in practically flat country, the rocks being chemically unalterable by atmospheric

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does not exceed the double or treble of the original value. Yet the absolute values of k, as determined for the same rock (in the dry state) by different observers, vary by more than tenfold. Provisional experiments on rocks in the naturally moist condition, conducted according to Mr. W. Voigt's method, show that the variations from rock to rock or those dependent on the conditions of bedding are far less important than is ordinarily assumed.

Concerning Table IV., it is remarkable how enduring in time and extended in space is the influence of eruptive magmas. It will be noted that there are regions where magmas, still in the molten condition, occur at comparatively shallow depths, and the investigations of several geologists have shown the extreme probability that volcanic eruptions herald their approach long beforehand by thermal phenomena. The author has thought out a simple alarm-signal, which, placed in a borehole some 100 feet deep or so, at the base of an active volcanic cone, and registering slight elevations in temperature, might give indications of an outburst many months before it actually occurs.

He considers that careful observation of volcanoes along these lines would be of far greater practical value than, and of quite as great theoretical interest as, the detailed and very costly investigation of seismic phenomena which is now everywhere the fashion. L. L. B.

THE DISTRIBUTION OF METALLIFEROUS ORES IN DEPTH.

Die Einteilung der Erze, mit besonderer Berücksichtigung der Leiterze sekundärer und primärer Teufen. *By* P. Krusch. *Zeitschrift für praktische Geologie,* 1907, *vol. xv., pages* 129-139.

The author, in a paper read to the German Geological Society, had already endeavoured to prove that certain ores are characteristic of what he terms "secondary" and "primary" depths respectively, and therefore may be regarded as good indicators for those depths. He then cited a few examples in support of his contention, but he now enters into a complete and detailed investigation of the subject.

If the mere quantity of ore be taken into account, the unaltered primary varieties may be well said to predominate, their uppermost limit being generally the underground water-level of the country, and the distribution of metal in them appearing to conform to certain definite rules. Above the underground water-level, a displacement of the original metallic content is manifest, and a just appreciation of the extent of that phenomenon furnishes a key to the right understanding of the particular ore-deposit with which one may happen to be concerned.

Stress is laid on the fact that every deposit to which the surface-waters have access is subject to alteration. The phenomena of decomposition are dependent on the nature of the ores, not on their genesis. Primary ores of similar character exhibit similar decomposition-changes under similar conditions, whatever their origin may have been. The "oxidation-zone" of ore-deposits is characterized by the oxides, carbonates, sulphates, chlorides, and more rarely the bromides and iodides of the heavy metals; while the "cementation-zone," at greater depths, where all the oxygen carried by the surface-waters has been used up, exhibits the enrichment due to the precipitation from undecomposed metallic sulphides, etc. If the processes of solution and reprecipitation extend over a very long interval of time, certain quantities of metal may accumulate just above the underground water-

level, having been perhaps originally dispersed over hundreds of yards (in depth) of primary ore-deposit; and a characteristic feature of the cementation- or concentration-zone is the appearance of native metals in large quantity, or at all events, of richly metalliferous sulphides and arsenides.

The investigation of an ore-deposit and a true estimate of its value must be based on the differentiation of ores into (1) oxidic ores; (2) cementation-ores; and (3) primary ores. But the ores of some metals have proved refractory to the displacement of their original metallic constituents, and consequently another classification, in a different order of ideas, also holds good: (1) ores with well developed oxidation- and cementation-zones; and (2) ores which, owing to their refractoriness, have suffered no variation in their original metallic constitution.

If the chemical action of erosion is, in certain localities, slower than the physical, the primary ore-deposit may there be seen to crop out at the surface; if the chemical action is the quicker of the two, then both the oxidation- and the cementation-zones may be observed, or the last-named alone, in which case it also crops out at the surface. Where the infilling of the lode is tougher than the country-rock, it forms a dyke or wall, enabling the most inexperienced prospector to "spot" the ore-occurrence and therewith the rich cementation-zone. On the borders of the newer mountain-belts where erosion has attained its maximum intensity, and in regions where glacial action has been a predominant factor, the usual decomposition-zones of ore-deposits have been swept out of existence, and therefore one must not always expect to find decomposition-zones, even in the case of ores which are prone to decomposition.

Starting from these premises, the author first of all considers the various occurrences of gold, pointing out that perhaps auriferous pyrites, in which gold is only an accessory constituent, is the most important ore of that metal. He animadverts on the serious mistake, to which many prospectors and engineers have laid themselves open within recent decades, of regarding the gold of the cementation-zone as primary, and assuming its continuance in depth. Where atmospheric agencies work faster than [redacted]

ores; and (2) the carbonates and silicates, the former group being richest in manganese, the author points out that the oxides and hydrates are very refractory to the decomposing action of surface-waters. On the other hand, the silicates and carbonates in the neighbourhood of the surface pass into oxides and hydrates (which in such cases are characterized by their porosity and generally cavernous structure). Wherever, therefore, workings in such ores have not penetrated below the underground water-level, the possibility exists of finding the primary ores, rhodonite and rhodocroisite, at greater depths.

Both nickel- and cobalt-ores are devisible into three clearly-defined groups: (1) the arseno-sulphidic ores, occurring in lodes similar to the sulphidic lead-silver-zinc lodes; (2) the oxidic ores, occurring chiefly in veins coursing through decomposed serpentine; and (3) the nickeliferous and cobaltiferous magnetic pyrites, which are original magmatic segregations from basic eruptives.

In the case of a complete section of a silver-ore deposit, the oxidation-zone is, on the whole, poor in the precious metal, the chloride being perhaps the most frequent silver-bearing constituent therein, with now and then a little native silver, and still more rarely the bromide and iodide of the metal. The cementation-zone is characterized by the occurrence of considerable quantities of native silver, silver-glance, antimonides and arsenides of silver, stephanite, silver fahlore, and red silver-ores (the last-named, especially, are practically confined exclusively to the cementation-zone). As at great depths in that zone, the original sulphides are often to a large extent present in their unaltered condition, it may be as well to point out how the primary galena, say, is distinguishable from the galena of the cementation-zone: in the former, silver is dispersed throughout in an extremely fine state of division, in such wise that an assay of as much as 16 ounces per ton is quite exceptional; in the latter, native silver is seen coating every crack and cranny, every pore and crevice, and assays of 320 ounces per ton, and even more, are not unknown. The same remark holds good of the argentiferous zinc-blendes.

With regard to the mercury-ores, it is important to note that the occurrence of cinnabar in the oxidation-zone does not always imply that the same ore occurs at greater depths; it may there, and more probably, be represented by mercury fahlores. In dealing with occurrences of native mercury, extreme caution is advisable in speculating as to which particular ore the metal has been derived from.

To those metals of which no oxidation- and cementation-ores (as defined by the author) are known, belong molybdenum, tin (in the form of cassiterite), iron (in the form of red and brown hæmatite), manganese (in the form of oxides and hydrates), wolfram, chromium, platinum, thorium, and aluminium. L. L. B.

ORIGIN OF PYROPISSITE OR "PARAFFIN-COAL."

Ueber die Entstehung des Pyropissits. By MAX HEINHOLD. *Jahrbuch der Königlich Preussischen Geologischen Landesanstalt und Bergakademie zu Berlin*, 1906, *vol. xxvii., pages* 114-158, *with* 3 *figures in the text.*

The mining district of Zeitz-Weissenfels in the Prussian province of Saxony is the only area so far known where pyropissite has occurred in sufficient quantity to justify the existence of a flourishing paraffin-industry based on the extraction of paraffin from it. The brown-coal formation there consists of a series of clays, loams, sands, gravels, and tough quartzitic

sandstones alternating in indeterminate succession. The brown-coal itself, however, forms a recognised geological horizon; it is an earthy dark-brown to black mineral, and yields an excellent fuel. With it is associated a black sandy dust, known to the hewers as *kokskohle* (coke-coal), of no economic value. When the brown coal becomes very rich in constituents susceptible of distillation, it passes into pyropissite, those parts of the seam being lighter in colour than the rest. This "paraffin-coal" in the fresh condition is a more or less plastic brownish mineral, greasy to the touch; on drying, according to its less or greater purity, it turns yellow or whitish, and crumbles away between the fingers. It has a dull, earthy, uneven fracture; but a fractured surface, if scratched with the finger-nail, becomes shiny. It ignites easily at a candle-flame, and gives off an aromatic tarry smoke. The author ascertained its average specific gravity to be 1·12. He supplies a bibliographical list of thirty entries, ranging chronologically from 1799 to 1905, and devotes the second chapter of his memoir to a synopsis of the views advanced and facts recorded in these publications, accompanied by a running commentary. In the third chapter he deals with the chemistry of the subject. On treatment successively with ether, benzol, and alcohol, the following percentage results were obtained with two samples of pyropissite from Gerstewitz:—

	No. 1.	No. 2.	Recent pyropissite from East Africa.
Soluble in ether	6·55	4·81	80·24
Soluble in benzol	36·45	31·09	3·86
Soluble in alcohol	2·11	8·43	6·24
Insoluble residue	54·89	55·67	9·66
	100·00	100·00	100·00

Further investigation with the same samples from Gerstewitz yielded the following percentage results:—

	No 1.	No. 2.
Hygroscopic water	4·84	5·26
Ash	7·84	14·88

[redacted]

etc., grains of pollen, epidermal fragments of dicotyledonous leaves, and fragments of coniferous cellular tissue having its meshes partly infilled with resin, partly empty, etc.

The Zeitz-Weissenfels district occupies a slightly undulating tableland, ranging in altitude from 660 to 1,000 feet above sea-level; and the Lower Oligocene brown-coal formation extends from the Rippach valley on the north to where the Elster cuts its way deep through the Bunter Sandstone on the south. It is split up by several valleys of erosion into separate patches, in each of which only one coal-seam appears to have been proved, and that not universally. Where neither the brown-coal formation nor the Bunter Sandstone have been laid bare by erosion, the whole country is mantled by drift-deposits. The entire thickness of the brown-coal formation ranges from 100 to 200 feet, and it rests conformably upon the Bunter Sandstone, its basement-bed being a bluish, greyish, or yellowish plastic clay of variable thickness. The main brown coal-seam is from 13 to 70 feet thick; and, in places, separated from it by a clayey parting, occurs another seam 3½ feet thick, yielding coal of inferior quality. Taken as a whole, the main seam is horizontally bedded, forming a series of very flat regular synclines. The occurrence of pure pyropissite therein is restricted to a few localities; and now, apart from some insignificant remnants at Aue, no unworked pyropissite remains, except under the village of Gerstewitz, where it is practically inaccessible. The pure mineral is said to have been found only in the lowermost portion of the main coal-seam, and generally at points where the seam is diminishing in thickness. It has been asserted that with the pyropissite was invariably associated the *kokskohle* or *schlackenkohle* ("clinker-coal") already mentioned, but not sufficient evidence is forthcoming nowadays to enable the author to test the full bearing of this assertion.

The pale-yellow beds of resinous vegetable wax (recent pyropissite) found along the banks of the Tana in the British East African protectorate, are probably drifted material derived from desert-plants that shed a variety of resinous wax; and in South Africa the widespread occurrence has been recorded of the geraniaceous plant *Sarcocaulon Burmanni*, the stems of which are covered with a crust of such wax, the function of which appears to be to prevent the dessication of the plant by protecting it against excessive evaporation. The natives, indeed, pick up the fallen stems, and use them as torches, whence they are known as "bushmen's candles." These recent examples throw light on the origin of the fossil pyropissite or paraffin-coal, which occurs in an area that in Tertiary times was probably covered with marshes and swamps, amid and around which flourished a luxuriant sub-tropical vegetation. A detailed account is given of the probable physical conditions, and consequently locally varying phenomena of decomposition, whereby from the same mass of vegetable material at one time or spot or horizon, brown-coal was formed, at another pyropissite, and at yet another clinker-coal. L. L. B.

CHEMICAL THEORY OF THE ORIGIN OF PETROLEUM.

La Genèse des Pétroles. By L. PERVINQUIÈRE. *Revue Scientifique, series* 5, 1908, *vol. ix., pages* 389-393.

Apropos of the recently published monograph of Dr. L. C. Tassart on the working, etc., of petroliferous deposits, the author reminds us that petroleum is not a substance of constant composition with definitely fixed properties: consequently, one ought rather to speak of natural oils, in the

plural. These natural hydrocarbons belong to three different categories, typified by the petroleum of Pennsylvania, the Caucasus, and Galicia respectively. The American oil chiefly consists of compounds corresponding to the formula C_nH_{2n+2}; that of Baku, of compounds belonging to the C_nH_{2n} series; while that of Galicia includes hydrocarbons of both series, together with aromatic compounds derived from benzene corresponding to the general formula C_nH_{2n-6}. This difference in composition, may, in part, account for the divergent theories put forward as to the genesis of petroleum: while all American writers, and not a few Europeans, uphold the organic origin of that substance, the Russians just as stoutly uphold its chemical origin. Several of those authors who consider that petroleum may quite well be the product of the distillation (owing to metamorphism) of plant-remains, have had the ground cut from under their feet by the recent observation of Mr. P. Sabatier, that the tars formed in the course of distillation of plant-remains or coal are made up of aromatic compounds with a large percentage of phenols and phenol-ethers, invariably absent in petroleum. Mr. Morrey considers that the Pennsylvanian petroleum was really formed from organic slimes by the agency of bacteria, and the experiments carried out by Dr. Engler would seem to lend considerable support to that view. On the other hand, those three illustrious chemists, recently deceased—Marcelin Berthelot, Moissan, and Mendeleieff, assigned an inorganic origin to petroleum; and the first two made the oil synthetically in the laboratory, though in neither case did they produce a petroleum of the same composition as that from Baku. Recently, however, Messrs. Sabatier and Senderens, using nickel as a catalysing agent, with a mixture of acetylene and hydrogen at a temperature of 392 degrees Fahr. obtained, after a lapse of 28 hours, a yellow fluorescent liquid possessing the characteristic odour and density of Pennsylvanian petroleum, and the same chemical composition. Using cobalt or iron under similar conditions, they obtained a brown or reddish oil, having the disagreeable odour that characterizes Canadian petroleum. By passing acetylene alone over nickel catalytically reduced from the oxide, heated to 400° or 600° Fahr., the metal incandesced, yielding thick fumes which condensed into a red green-shot

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THE ORIGIN OF PETROLEUM, ETC.

(1) *Zur Frage der Entstehung des Erdöles und der Steinkohlen.* By A. F. STAHL. *Chemiker-Zeitung,* 1905, *vol. xxix., No.* 49, 6 *pages; and*

(2) *Einige Bemerkungen zum Artikel Prof. H. Potoniés: Zur Frage nach den Urmaterialien der Petrolea.* By A. F. STAHL. *Chemiker-Zeitung,* 1906, *vol. xxx., No.* 3, 2 *pages.*

In considering, from the geological point of view, the formations in which workable deposits of petroleum occur, the observer cannot help noticing a distinct petrographical and lithological resemblance between them, to whatever different periods they may respectively belong, and so we are practically entitled to speak of a common "petroleum-facies." The rocks of this facies are predominantly alternating beds, of variable thickness, of marl, shale, clay, sandstone, conglomerate, and limestone, with intercalations of gypsum and rock-salt. The constancy of this facies, moreover, entitles us to assume that the oil therein is a primary deposit, and so the substances from which it was formed must be looked for in that group of rocks. The author holds that these substances were predominantly but not exclusively of animal origin: where great masses of animal organic matter occur, there must be a certain accumulation of vegetable matter also, since such matter constitutes, directly or indirectly, the nutriment of animal organisms. It is not the higher forms of animal life, such as fishes, that furnished the greater part of the material for the world's petroleum-deposits, but rather such microscopic creatures as now swarm in salt-lakes, in certain gulfs and littoral sea-belts, or even in larger pelagic areas (like the Black Sea, the Caspian, or the Sea of Aral), their remains, commingled with clay and sand, forming vast deposits of black mud. For instance, a boring put down in the Inderek salt-lake, on the road from Uralsk to Guryev, has proved black muds, alternating frequently with layers of rock-salt, clay, and sand, for a depth of several hundred yards. The "black muds" of earlier geological periods now present themselves to us in the guise of bituminous shales and slates. The question then arises by what process natural oil was formed from such material. It has been usual to postulate high pressures and possibly high temperatures—but the author regards the distillation-theory as untenable. He points out also, that, even granted simultaneity of great pressure and high temperature, it is chemically impossible to combine into oil or into any compound approximating thereto, the atoms of a mixture of carbon and hydrogen-gases.

In the course of slow decomposition of organic substances sealed up from the air by layers of clay, and subjected to the pressure of the overlying rocks, among other gases large quantities of hydrogen-sulphide are evolved from the albuminous matter and carbon from the cellulose. Now, the organic substances contain a certain amount of iron-oxide, as does also the underground water; but the carbon acts as a reducing-agent, and the iron thus liberated, by reason of its great affinity with the sulphur of the hydrogen-sulphide, combines therewith to form pyrite. Carbon and hydrogen being thus liberated at the same moment, they hasten to recombine, forming the fluid hydro-carbons, otherwise known as petroleum—the quantity thus formed bearing a definite relation to the amount of carbon liberated.

The consequence is, that more or less pyrite is always found in the rocks of the petroleum-facies; where the strata at a subsequent period have been dislocated and subjected to the influence of atmospheric agencies, limonite, or clay-ironstone, or, under certain circumstances, sphærosiderite

is found in them. As an example which confirms his theory, the author cites an occurrence in the petroliferous region of Daghestan, where the iron present in the form of sphærosiderite in a 21-foot bed corresponds to the quantity of carbon sufficient to produce the probable volume of natural oil available in the Tertiary strata there.

From the plant-remains to which the author referred in speaking of the origin of petroleum coal was formed, and he agrees with Dr. H. Potonié in thinking that this happened on the very spot where the plants lived and died, noting in this connexion that the floor of a coal-seam rarely contains distinct plant-impressions while the roof is generally rich therein. Whence it can only be inferred that here the plants grew, new generations arising on the very spot where the old had rotted away, until extensive depressions were filled with peat and a forest-flora; then, sinking below the level of the sea, they were overlain by sedimentary deposits. Similar changes of level are just as manifest in the petroleum-facies as in the coal-measures, but we have in the former, not so much to deal with shallow seas invading the land, as to remember that deep waters often in the former swallowed up the land, and so the overlying deposits are characterized by different features.

For what reason the hydro-carbons derived from vegetable matter are oxidized with greater facility than those derived from animal matter must at present remain an open question, but it is possible that the resins existing in plants have some sort of influence on the chemistry of the process. The variation in character of the petroleums from different beds and different localities may be assignable to the greater or less intermixture of vegetable with animal matter, or to the mechanical intermingling of fats, resins, and wax-like substances elaborated in and from both animal and vegetable organisms.

Just as a certain amount of vegetable matter was undoubtedly commingled with the animal matter from which petroleum was formed, so a certain amount of animal matter was commingled with the plant-remains from which coal was formed: in the decomposition of these plants, microscopic animal organisms played a considerable part. On the whole, there [redacted]

Geological Society of South Africa that in the Vaal river-basin, at all events, the diamonds must originate from diabasic rocks: they differ in every respect from all known kimberlite-diamonds. He quotes at considerable length the paper which he read at Johannesburg, and points out with legitimate satisfaction that his views are confirmed by Prof. T. W. E. David's find of diamonds in diabase in Australia.

With regard to pegmatite, Dr. Corstorphine has shown that there is no doubt that pegmatitic dykes are the original matrix of the Somabula diamonds. Diamonds have now, therefore, been shown to occur not only in strictly basic, but in basic-intermediate and acidic rocks. It is also established that olivine and iron-minerals are by no means invariable associates of the diamond in its original matrix. L. L. B.

THE FORMATION OF KAOLIN.

Über Kaolinbildung. *By* H. Stremme. *Zeitschrift für praktische Geologie*, 1908, *vol. xvi., pages* 122-128.

Premising that the protagonists of both the opposing theories of kaolinization which at present chiefly hold the field neglect to adduce experimental chemical data in support of their respective contentions, the author states that he has spent more or less six years in working out the problem from the chemical side. He tabulates first of all analyses exhibiting the contrast in chemical composition between the products of atmospheric weathering of granites and porphyries and those of kaolinization of similar rocks. The considerably greater leaching-out of alkalis and iron in the latter case is conspicuous: granted that both processes are the work of feeble acids, weathering may be generally characterized as a process of oxidation; while kaolinization, so far from being an oxidizing process, may actually be one of reduction. The part played by hydrogen-sulphide in presence of feeble acids, ultimately fixing the iron in the rocks upon which it acts in the form of iron-pyrites, is discussed, as also the conditions under which kaolinization may (in certain cases) be the result of post-volcanic phenomena. For many reasons, adduced in detail, the author holds that certain flat widespread deposits of kaolin or china-clay are the outcome of the action of peat-moor waters on the underlying granites, etc.

He summarizes his main conclusions as follows:—Atmospheric weathering, decomposition by post-volcanic gas-emanations, and decomposition by peaty waters differ therein, that in the process of weathering the iron contained in the rocks is fixed in the form of oxides; that in post-volcanic decomposition, in presence of feeble acids, with abundance of water and exclusion of air, the iron is usually fixed in the form of pyrites; but that in peaty-water decomposition the iron is principally leached out. Consequently, he assumes that kaolin of industrial value is usually formed from ferruginous rocks by the action of peaty waters. In all three processes, carbonic acid is the chief decomposing agent, and so in all three felspar is decomposed to kaolinite; or, if decomposition has not been long continued, it is, at all events, altered "in the direction of kaolinite." Rocks more or less free from iron may also be altered into kaolin by feebly acid gaseous emanations with exclusion of air, or by the chemical agencies of atmospheric weathering. Springs charged with carbonic acid are perhaps among the most potent post-volcanic agents of kaolinization; but thermal waters constituting more or less saturated solutions of salts, instead of decomposing the felspars merely into kaolinite, alter them still further into substances poor in silica. L. L. B.

PRECIOUS GEMS AND RADIO-ACTIVITY.

(1) *Contribution à la Synthèse des Pierres précieuses de la Famille des Aluminides.* By F. BORDAS. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences*, 1907, *vol. cxlv.*, *pages* 710-711.

In nature, the varieties of corundum range from transparent colourless sapphire, through yellow, green, blue, and pink sapphire, to brown and opaque corundum (usually so called), and it is held that this variety of coloration is due to the presence of traces of various metallic oxides (iron, manganese, chromium, titanium, etc.). Recent experiments, however, have led the author to the conclusion that the presence of any particular metallic oxide does not actually determine the coloration of these precious stones. He finds that he can vary their coloration by submitting them to the action of bromide of radium; by graduating the activity of this bromide, or by increasing or decreasing the distance between the precious stone and the radio-active halogen-compound, the intensity of the reaction may be correspondingly diminished or increased. He can make a sapphire pass in this way from the initial red to the violet, thence to the blue and the green, and finally from the green to the yellow. According to this succession of changes, it would appear that the ultimate term of the series is the yellow tinge characteristic of topaz.

The hypothesis suggests itself that in the regions where these precious stones occur, the neighbouring soil (or rock) is endowed with a certain amount of radio-activity. It may be noted that yellow sapphires are the commonest of sapphires, and that sapphires which are in part blue and in part yellow are often found, this bipartite coloration appearing to indicate that the gems undergo in nature a slow modification analogous to that which the author has more rapidly effected in the chemical laboratory.

(2) *Action du Bromure de Radium sur les Pierres précieuses de la Famille des Aluminides.* By F. BORDAS. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences*, 1907, *vol. cxlv.*, *pages* 800-801.

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(3) *Sur la Coloration de certaines Pierres précieuses sous les Influences radio-actives.* By DANIEL BERTHELOT. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences*, 1907, *vol. cxlv.*, *pages* 818-820.

Mr. Daniel Berthelot, the son of the illustrious chemist recently deceased, gives an account of experiments, on much the same lines as those first described, started by his father on November 15th, 1906, and continued by the son until October 30th, 1907. Colourless quartz and colourless fluorspar showed not the slightest change; but amethystine quartz and violet fluorspar, after being discoloured by artificial means, recovered their lost oxygen when submitted to the action of radium, and resumed their original coloration. The heart of a crystal of the intractable, well cleaved, colourless fluorspar, placed in a saturated solution of acetate of manganese, and then subjected to the action of radium, assumed a pinkish tinge. Apparently the molecular bombardment of the radium-rays carried into the interior of the crystal sufficient traces of metallic salt to colour it slightly. Probably the cleavage-planes facilitate the phenomenon, for there is scarcely any perceptible coloration in the case of a specimen of colourless quartz subjected to the same procedure.

A green emerald from the Tyrol, discoloured by heating in a long narrow tube, failed to resume its original coloration on being exposed to the action of radium. Admitting that the coloration of the natural emerald is due to hydrocarbons, it would seem evident that the organic colouring-agent is irretrievably destroyed by heat.

It may well prove feasible, however, at some future time, to reproduce by means of radio-activity, the natural coloration due to hydrocarbons (such as that of the emerald and of green fluorspar), the electrified radium-rays effecting first of all the synthesis of the colouring-principle and then its diffusion in a colourless crystal, much as fluorspar can be coloured, as above mentioned, at the expense of acetate of manganese. L. L. B.

METALLIFEROUS MINES OF STYRIA, CARINTHIA, AND CARNIOLA, AUSTRIA.

Der Erzbergbau in Steiermark, Kärnten, und Krain. By DR. — AHLBURG. *Zeitschrift für das Berg-, Hütten- und Salinen-wesen im preussischen Staate*, 1907, *vol. lv.*, *pages* 463-521, *with* 28 *figures in the text and* 2 *plates.*

In order to elucidate his remarks on this subject, the author considers it prudent to begin with a general synopsis of the geological structure of the Eastern Alps. He points out that no portion of the great Alpine belt shows so clearly the triplicate division into a northern and a southern limestone-belt and a central crystalline-schist *massif*. The northern margin of the central zone is sharply defined by the longitudinal valleys of the Inn, the Salzach, the Enns, the Salza, and the Leitha, but its southern margin, although not deficient in longitudinal river-valleys, is by no means so clearly defined.

Among the ore-deposits of the Eastern Alps those of zinc and lead still rank as of high importance. They are found chiefly in Carinthia, and occur almost exclusively in the Upper Trias. The famous mining centre of Raibl lies not far from the borders of Carniola and Italy in a small transverse valley, cut in the Veneto-Julian Triassic plateau. The deep ravines or *klamme*, which run north and south down from the Königsberg, are the outward expression of the faulting and lateral thrusting which the rocks have undergone, and each of them marks the occurrence of

an ore-deposit within the dolomites. The ores do not bear universally the character of lodes, but assume in some cases a bedded appearance, and a connexion can be traced between them and the "fish-slates" which overlie the dolomites. These ores are predominantly a very pure, markedly pale, blende (often distinguishable only by its weight from the country-rock), and an equally pure galena. In the latter antimony and copper-impurities are conspicuous by their absence, and arsenic is found only in infinitesimal quantity. No gradual passage is observable from the ores into the country-rock, and the hypothesis of metasomatic replacement is therefore excluded. There appears to be, in fact, no doubt that the ores are the result of precipitation from metalliferous solutions within pre-existing cavities in the dolomite. Near the surface oxidic ores occur, among which calamine especially is of industrial importance. The author is inclined to regard all of these as the decomposition-products of the deeper-lying sulphidic ores, whereas Dr. Pošepny ranges them in two categories: one of primary deposition, and the other of secondary deposition. However that may be, there is no question but that the calamine is the outcome of metasomatic replacement of the ore-bearing dolomite; with it is invariably associated brown iron-ore, and occasionally cerussite, silicated zinc-ore, etc. The mineral industry of Raibl dates back to early medieval times: at present the workings belong in part to the Government, and the other part (since the beginning of the 'nineties) to Count Henckel von Donnersmarck. The average monthly output from the latter's mines averages 1,000 tons of smeltable ore, and the main winding-shaft has been sunk to a depth of 460 feet. The extreme variability in thickness of the ore-body constitutes one of the chief difficulties in working. Siemens and Halske's electric drills are in use.

Of equal importance with the mineral-industry of Raibl, and dating back to far more remote times, is that of Bleiberg. The stratigraphical conditions of the deposits are in many respects very similar; but the ores occur principally at the intersections of transverse fissures with certain bands of the Wetterstein dolomite, and thus the form and trend of the [redacted]

Just as the most important lead-and-zinc ore-deposits of the Eastern Alps are centred in Carinthia, so the workable deposits of mercury-ore appear to be confined to Carniola. The world-renowned quicksilver-ores of Idria were discovered in 1490 by woodcutters; after many vicissitudes, the mines were taken over in 1580 by the State, in whose hands they still remain. The tectonics of the district are extremely complicated, but there appears to be no doubt that the deposition of the ores is traceable to a transverse fissure (one of the results of intense post-Cretaceous disturbances) in a mass of Triassic rocks wedged between two great overthrusts. The ores are invariably found, either within the Wengen Shales, or in their immediate neighbourhood, and the shattered condition of these is presumed to have furnished convenient surfaces for the precipitation of the cinnabar from the vapours in which it was borne upwards from great depths. Native mercury occurs at a particular horizon—the Gailthal Shales, which overlie the cinnabar-deposit (in abnormal succession) at the northern margin. The author discusses briefly, and if anything favourably, the prospects of an extension of the ore-bodies both in a southerly direction and in depth. At present, five shafts are in active work, the daily haulage amounting to 400 wagons (a total of 320 metric tons). The entire output is sent to the Government smelting-works, a mile and a quarter down stream from Idria, after a preliminary sorting at the pit-mouth. A detailed description is given of the treatment of the ore (the wet process has long been discarded) and it is stated that the output of metallic mercury from these mines alone in 1905 amounted to over 519 tons. Two other important localities for cinnabar in the same province are cited, Neumarktl in Upper Carinthia, and Littai in Lower Carinthia; but in both cases, after spasmodic revivals, the mineral-industry has been at a standstill for several years. In the Southern Karawanken, however, certain cinnabar-deposits of apparently considerable extent were opened up in the early 'nineties; but the poverty of the ore and the difficulties of transport have checked their further development.

One ore of iron alone, spathic iron-ore, is of supreme importance in the Eastern Alps. To it, however, Austria owes her seemingly inexhaustible wealth in the raw material necessary for the manufacture of iron and steel. It appears to be restricted to three well-defined belts, the most considerable of which (the North Alpine Permian) ranges almost throughout the entire Eastern Alps from Schwaz in Tyrol, passing by Salzburg and the whole of Upper Styria into Lower Austria, attaining its greatest development in the famous Erzberg of Eisenerz. The second and less extensive belt is intercalated among the mica-schists of the central *massif*; while the third and southernmost is associated with the Upper Carboniferous rocks of the Karawanken. Ringed round by mighty hills, the cone of the Styrian Erzberg soars in lofty isolation to a height of 5,040 feet above sea-level: it has been the site of mining operations since time immemorial, and until the second half of the nineteenth century the workings were mainly underground. At the present time these have been entirely given up, and opencast workings are conducted on a colossal scale over a vertical height of 2,000 feet, at 50 separate levels. The annual output between 1891 and 1900 was doubled, a very slight decrease being manifest in recent years (the output for 1905 amounted to 1,064,529 metric tons or about 61 per cent. of the total Austrian output).

Hüttenberg in Carinthia represents the greatest development of the second iron-ore belt. Here too, mining operations date very far back, to the times of the ancient Romans at least. The stratigraphical conditions

are very complicated, and have given rise to many divergent theories concerning the genesis of the ore-deposits. The iron-ores are invariably associated with saccharoidal limestones, which, by dint of taking up mica, pass occasionally into calc-schists: the metalliferous deposits are found sometimes at the contact of the limestones with mica-schists, and exceptionally they wedge out into the mica-schists too. They are of approximately lenticular form, and are very iregular in regard to the horizon at which they occur—that is, whether near the top, or near the bottom, of the limestones. The bulk of the evidence points to metasomatic replacement of the limestone by ores precipitated from thermal waters percolating upwards through fissures in the rock. The mineral-industry hereabouts has greatly dwindled since 1893; in 1905, the number of workpeople employed had shrunk to 176, and the output to 16,649 tons. This is, however, by no means due to any impoverishment of the ores, but to the settled determination of the concessionaires to concentrate their energies on the Styrian Erzberg, where the economic conditions are vastly more favourable for profit-taking.

Little need be said about the iron-ore belt in the Karawanken, since mining operations thereon are in a state of suspended animation; but the ferro-manganiferous ores of the southern flank of the Vigunšica are of noteworthy importance. The ore is a semi-loamy semi-plastic material, containing from 20 to 40 per cent. of manganese, intercalated among the limestones in a band varying in thickness from 6½ to 16 feet. It is most probably of metasomatic origin. Working is conducted (during the summer months only) under primitive conditions.

The remainder of the memoir deals with deposits which are not at present of any considerable industrial importance, such as the abandoned gold-mines, the pyrites-deposits (which are still being worked), the chrome-iron ores of Kraubert, the graphite-deposits of Upper Styria, and the talc-deposits of Mautern in the Liesing valley. L. L. B.

BROWN COALS OF BJELINA, NORTH-EASTERN BOSNIA.

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from the overlying Cretaceous Limestones; and these again are, in the weathered condition, very similar to the much more recent (Middle Miocene) Leitha Limestones. The littoral marine Eocene strata cover a vast area, and form practically the basement-rocks of the coal-bearing fresh-water Upper Oligocene and Lower Miocene. The Leitha Limestones unconformably overlie the latter as well as the Eocene, and hence it may be inferred that a considerable interval elapsed between the deposition of the brown coals and the invasion of the Middle Miocene sea. The two main epochs of tectonic disturbance in the region were just before the Leitha Limestones were laid down, and immediately after the deposition of the uppermost *Congeria* Beds, that is, probably about the beginning of Quaternary time.

It had been at one time supposed that three coal-basins were in existence, but there is really only one basin, cut up by later disturbances and erosive agencies. The rock-succession therein is divisible into a barren lower group and a productive upper group: the former consists predominantly of red and green mottled clays, soft red sandstones, and conglomerates; the latter of pale-grey marls in places crammed with Cypridea, and green and grey often sandy shales, with the frequently very thick brown-coal seams. Owing to repeated folding and faulting, the brown-coals of Vgljevik-Priboj are split up by the outcropping of the barren group and even of the basement rocks into four distinct "fields"; those (1) of Vucjak-Glinje or Vgljevik proper; (2) of Mezgraja-Jasikovac; (3) of Tobut-Peljave; and (4) of Priboj, ranging from north-east to south-west. The most numerous outcrops of coal occur in the first-mentioned, and generally speaking the seams diminish in thickness towards the south-west, but the quality of the mineral apparently improves in that direction. While in the north-east the seams are associated with cypridiferous marls and overlie mottled clays and rotten quartz-conglomerates, in the south-west they are associated with flaggy freshwater limestones and overlie principally red sandy clays and calcareous conglomerates. It would seem that the Oligocene-Miocene lake-basin in which the brown coals were laid down was filled up progressively from south to north.

A detailed description is given of the four above-mentioned "fields." In the first the two most important seams are respectively 40 and 33 feet thick, and the coal from the thicker seam yielded on partial analysis 10 per cent. of ash, 12·26 per cent. of water at 230° Fahr., 41·82 per cent. residue from vaporization, and a high percentage of sulphur (not stated): heating power=3,971 calories. Analyses are given from other localities, but do not alter much the impression conveyed by the analysis just cited. The second coalfield affords but few favourable exposures, and yet in former years it was the most actively worked of the four. Parts of the main seam here have been (by some unexplained natural phenomenon) "burnt out"; where the coal is in its original condition it is less lignitic than elsewhere, and passes into a sort of "parrot-coal." Analysis of a specimen of a dark brownish-black colour with pitchy lustre yielded the following results:—humidity at 230° Fahr., 16·10 per cent.; ash, 9·66; residue from vaporization, 45·12; heating power, 4,269 calories. In both the fields just mentioned, three groups of seams somewhat compressed together may be distinguished. In the third "field" the bedding is less disturbed, but on the other hand is of deeper-water origin. The stratigraphical conditions are such as to justify the expectation that underground workings here would strike a better and more durable coal than the Vgljevik opencast workings. No outcrop has been found showing a mineral comparable with the 33-foot seam of the

more northerly fields; the 40-foot seam is represented by one which yields coal of variable character: for instance, one layer is of a compact lustrous velvet-black mineral with perfect conchoidal fracture; other layers, although of a rich black and very lustrous, are undoubted lignites of fibrous structure. The heating power ranges from 4,227 to 4,527 calories, and the percentage of ash from 8·05 to 6·40; the lignitic coal contains rather more sulphur than the other. In the fourth coal-field, what is supposed to be the main seam yields a coal of beautiful appearance and good heating power (4,520 calories), yet containing as much as 10·42 per cent. of sulphur. On the other hand, a seam 6½ feet thick exposed in the Corkov valley yields a rich black lustrous coal all but free from sulphur, with only 3·16 per cent. of ash and a heating power of 4,705 calories. On the whole, the Tobut-Peljave and the Priboj "fields" are likely in the near future to be the scene of more active mining operations than the other (at first sight) more favourably circumstanced "fields." L. L. B.

THE FAHLORE AND MERCURY-ORE DEPOSITS OF BOSNIA AND HERZEGOVINA.

Die Fahlerz- und Quecksilbererzlagerstätten Bosniens und der Hercegovina. By FRIEDRICH KATZER. *Berg- und Hüttenmännisches Jahrbuch der k. k. montanistischen Hochschulen zu Leoben und Příbram*, 1907, *vol. lv.*, *pages* 145-265, *with* 25 *figures in the text and* 1 *plate.*

The fahlores take high rank among the useful minerals of the two occupied provinces as, besides being rich in copper, they are also notable mercury-bearing ores. In the world's copper-output fahlores play as a rule a very subordinate part; for, although they may be richly mineralized, their distribution is too restricted, and a good yield of copper from them is only attainable in certain localities; in Bosnia they happen to be of prime importance, and the Maškara smelting-works, for instance, have for many years past been fully taken up with the treatment of fahlores alone. The mercury-ore deposits proper of Bosnia and Herzegovina occur chiefly in the form of lodes and impregnations of cinnabar, and for the time being they

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west against the Trias and the Tertiary. The principal metalliferous lodes belong to a system of fissures striking north-west and south-east, which is intersected by another system striking from north-east and south-west to almost due north and south. Rarely do the troublesome north-east and south-west fissures constitute metalliferous lodes; but the north-and-south fissures are often infilled with the same minerals as the principal lodes, although they are of no considerable extent along the strike, whereas several of the principal lodes can be traced for miles. The lodes cut through all the Palæozoic rocks without their infilling being apparently affected by the passage from one rock-group to another. This independence of the mineralization in regard to the country-rock implies that the force which impelled the upwelling of the metalliferous solutions was very great, and also that the fissures must have extended to considerable depths. The Maškara main lode is infilled with mercury-bearing fahlore, siderite, baryte, quartz, and calcspar; dolomite is of quite subordinate occurrence, and pyrite is rare. Decomposition-products are found, in the shape of limonite hæmatite, malachite, and azurite; chalcopyrite, cinnabar, and metallic mercury seldom occur. Analysis of the pure fahlore has yielded the following results: copper, 38·41 per cent.; antimony, 27·43; mercury, 7·58; sulphur, 21·62; zinc, 0·72; iron, 2·8; magnesia, lead, arsenic, etc., in trifling quantity; 0·005 per cent. of gold; and 0·152 per cent. of silver. Analyses of other samples have yielded as much as 16 per cent. of mercury, with an almost complete absence of arsenic; no single specimen of the ore has been found from which mercury is absent. The main lode is worked by six drifts or adits, spaced over a vertical height of 332 feet. A great extension of the workings is expected in the direction of deeper levels; the smelting-works and the whole installation will then be enlarged, and Maškara promises to become one of the most important centres of the mineral-industry in Bosnia. North-west of that locality, prospecting-work has been done on the metalliferous lodes of Šeferoviči; a selected sample of fahlore from these yielded 35·71 per cent. of copper; 18·37 of antimony; 3·91 of mercury; also 216 grains of gold and 38·26 ounces of silver per metric ton. Farther north-west again, shallow workings have opened up the rich lodes of Mračaj, which are at their richest and thickest while they course through the Permian limestones: the gangue is partly sideritic, partly barytic; but the siderite predominates, and the rich fahlore (the first-formed mineral in the lode) appears to be more especially associated with it. In copper- and in mercury-percentages the ore is quite equal, as the analyses show, to the Maškara mineral. More or less detailed descriptions are given of the fahlores of Dobrošin, Seoci, Rad, Saski Rad, Borova ravine, Cvrće, Djamuš hill, Haslibrdo, Daganj ravine, Valice, Crkvica, Kulentaš hill, Budišna ravine, Parsovići, Koto, Slatina, Orlovac, Dobrigošće, Ježurine, Žaovine, Otomalj hill, Fojnica, Bakovići, Kreševo, Toplica, Tarćin, etc.

The cinnabar-deposits of the Zec Planina are associated with the nests, stockworks, and beds of hæmatite (probably of metasomatic origin) which occur among the yellow or brownish, cavernous Upper Permian limestones. The cinnabar occurs rarely within the hæmatite itself, but is usually found just above it, in the "roof" or "hanging-wall." Seldom does this cinnabar contain as much as 25 or 30 per cent. of metallic mercury; indeed the general percentage ranges from barely 2 to something over 23. The author assigns the reasons for which he regards these deposits as comparatively superficial; they have been largely worked out, and the attempts made in the years 1889-1892 to follow them up below the limestones met

with results which do not encourage the hope of any permanent revival of mining operations on the Zec Planina. South-east of this massif stretches the Pogorelica Planina, which drops very rapidly to the level of 3,608 feet above the sea: here too, the cinnabar-deposits in the Permian limestones were worked out several years ago, and the same statement would seem to hold good of the deposits of the neighbourhood of Deževica and Kreševo, and of the triple-peaked Inač hill-group. Among the Carboniferous phyllites north-west of Fojnica, a series of six parallel lodes are discerned on each flank of the Cemernica valley, forming together a great metalliferous belt, which can be traced for a distance of a mile and a quarter. The vast intrusions of quartz-porphyry, which have invaded the phyllites some little distance away to the north and west, may no doubt have some more or less direct casual connexion with the mineralization of these lodes. They have been largely worked out by successive generations of miners; but it is by no means certain that mercury was the ore sought for in the olden days. If the opinion advanced by various investigators, that the ancient miners worked these lodes only for the gold and silver which they could get from them, be correct, considerable quantities of cinnabar must be yet lying untouched in the old workings. Indeed, exploration-work in the year 1890 revealed repeatedly unworked portions of lodes rich in mercury. The gangue is of a quartzose character, and the lodes are mineralized chiefly with antimonite, zinc-blende, and cinnabar. Deep-level workings initiated on a large scale are not unlikely to meet with success: the neighbouring country is well watered by streams which have a sufficient fall to keep an electric power-plant going; and enough gold, etc., can be extracted from the old waste (gangue-material) to cover much of the initial expenditure. A description is given of the cinnabar-bearing lode of Zahor, which has, however, been prospected chiefly for its zinc-blende. Far away from the occurrences hitherto enumerated is the Draževici cinnabar-deposit, in the manganese-ore district of Čevljanovič, north of Sarajevo. Its geological conditions are compared by the author with those of the famous Almaden deposit in Spain.

With the exception of the Draževići deposit, all the notable occurrences of fahlore and cinnabar in the occupied provinces are concentrated within

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quently enough with shales. Certain fetid limestones, as at Kolozsvár and Szacsal, moreover, are impregnated with bitumen. South-west of Nagybánya, about 2 miles from the hamlet of Monostor, petroleum and ozokerite are found in limestones, which form inclusions of considerable dimensions within mica-schists. The rhyolite-tuffs of some localities are saturated with bitumen, and in the rhyolitic quartz-trachyte of Kiskapus asphalt occurs filling cavities and fissures of the rock. Finally, at the copper-mines of Recsk, a biotite-hornblende-andesite has been laid bare, with small cavities containing drops of petroleum.

The two chief petroleum-bearing regions of Hungary are situated, one along the north-eastern border, and the other along the south-western border of the kingdom; in age and in structure the beds are as widely different as they are far apart in space. The petroleum-belts in the north-eastern Carpathians, in the counties of Sáros, Zemplén, and Ung, striking parallel one with the other from north-west to south-east, can be followed up across the frontier into the Galician oil-field. In tracing these belts south-eastwards along the inner margin of the Carpathian range, a tremendous break is observed between Máramaros county and the Tölgyes Pass in Transylvania: at the last-named locality the oil-bearing Flysch-beds re-appear, continuing thence uninterruptedly as far as the neighbourhood of Brassó. The Flysch-belt on the outer margin of the Carpathians falls partly within Galician and partly within Rumanian territory, but two petroliferous localities in Hungary belong to this outer margin (Sósmezö and the upper Putna valley in Háromszék county). The south-western oil-field comprises the Muraköz district, Zala county, and Croatia-Slavonia; the two petroliferous belts within it can be traced for mile after mile along the same strike—from north-west to south-east. One of these, extending from Muraköz parallel with the river Drave, is not far short of 50 miles in length; the other runs parallel with the river Save.

The oil-bearing strata of Hungary are predominantly of Tertiary age, but there are a few petroleum-deposits which date as far back as the Trias, the Lias, and the Cretaceous Periods.

A brief history is given of the search for petroleum in the Magyar kingdom, divided into three epochs: (1) that from 1850 to 1880, when such work as was accomplished was merely superficial in character, and was initiated with scant knowledge and less capital; (2) that from 1881 to 1893, when exploration was conducted with some justifiable pretence to technical knowledge, and was backed up by a sufficiency of funds; and (3) that from 1894 to the present day, during which deep borings have been put down, and private enterprise has been strengthened by subsidies from the Hungarian Government. Experience has shown, however, that these subsidies have not made for real progress.

The author gives a detailed description of each of the north-eastern petroliferous areas in the following order: Trencsén county (Turzófalu); Sáros and Zemplén counties; Ung county; Máramaros county; Csík and Háromszék counties; the inner basin of the Transylvanian region; and the north-western margin of the Magyar-Transylvanian frontier-range. He then describes the asphalt-deposits which impregnate the Pontic sands below the drift-clays, at the western base of the Réz hills in Bihar county, Reverting to petroleum he gives a short account of the occurrences in the Mátra range and in the neighbourhood of Nagybánya, followed by a brief description of the bituminous shales of Stájerlak. The south-western petroliferous areas are then described in detail.

Statistics of output are given, showing how unimportant a part Hungary plays as a petroleum-producer: in the single year 1905, Galicia yielded more than 15 times as much mineral oil as had been got from the entire Magyar kingdom in the preceding 45 years. A dozen analyses of petroleum and eight analyses of ozokerite-sands and bituminous shales are tabulated.

In a retrospect of what has been accomplished in regard to the Hungarian oil-fields during the past half-century, the author remarks that unluckily the pen has been far busier than the boring-tool. Actual mining operations are practically confined to the Muraköz district; but the Flysch-belt of the Carpathians has not been thoroughly investigated, and Hungary's possible resources in petroleum remain an open question. Meanwhile the manner in which concessions have been monopolized constitutes a check to mining enterprise. L. L. B.

IRON-ORES OF THE PAYERBACH-REICHENAU DISTRICT, LOWER AUSTRIA.

Die Eisensteinbergbaue der Umgebung von Payerbach-Reichenau (Niederösterreich). *By* KARL REDLICH. *Berg- und Hüttenmännisches Jahrbuch der k. k. montanistischen Hochschulen zu Leoben und Příbram,* 1907, *vol. lv., pages* 267-294, *with* 1 *figure in the text and* 2 *plates.*

After a brief introduction summarizing the literature of the subject, the author gives an account of the history of the mineral-industry in this region, an industry of which the birth dates back many centuries. The earliest time, however, from which documentary evidence is extant is about the middle of the sixteeenth century, when apparently the deposits were worked for copper (chalcopyrite) but not for iron. The value of the latter metal was nevertheless fully recognized in the concessions granted before the seventeenth century had drawn to a close, and thenceforward, with many vicissitudes and interruptions caused by wars, etc., the industry continued until about 1892, when the stress of modern competition compelled its abandonment. In 1894 a determined effort was made to revive it, but mining operations were finally stopped at Hirschwang in 1902 and

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The rock-groups already enumerated are of undoubted Palæozoic age, and are overlain by the Triassic (Werfen) shales and limestones. A fault, giving rise to the valley of the Kleinau river, separates the Hirschwang-Altenberg-Kleinau district on the one hand, from the Schendlegg-Schwarzeck district on the other: and the ore-belts, which in the former strike due east and west, in the latter strike north-eastwards. The most considerable output has been obtained from the above-mentioned 3rd ore-belt, which has the coarse conglomerate for its footwall and the red and green schists for its hanging-wall: it is probably of the same age as the Grillenberg ore-deposit and lies at about the same altitude, but, as already stated, at Grillenberg, the slates occur below the ore-body and the conglomerate above it. The workings at Altenberg opened up a deposit 250 feet thick (including partings and unworkable ore) over an uninterrupted length of 350 yards.

The minerals in the above-described deposits include siderite, ankerite, pyrite, chalcopyrite, arsenical pyrite, antimony fahlore, baryte, cinnabar, quartz, calcite, specular iron-ore, limonite, vivianite, azurite, malachite, native copper, etc. The siderite is intimately intermingled with the ankerite in granular masses or in fairly large crystals, and contains on an average 34 per cent. of iron and sometimes as much as 20 per cent. of silica. In 1901, certain ores upon smelting yielded, according to averages spread out over many months, 53 per cent. of the metal. A couple of detailed analyses are tabulated. Next in importance to the siderite is the chalcopyrite, which occurs either impregnating the iron-ore in a very fine state of division or in nodular masses varying in size from that of a man's fist to that of a man's head. The antimony fahlore is intergrown with the chalcopyrite; it is of a pale steel-grey colour, and analyses show that it contains a certain amount of gold and silver.

Discussing generally the origin of the ore-deposits in this sub-Alpine region, the author arrives at the following conclusions:—The siderite-chalcopyrite deposits are practically conformable with the Palæozoic strata among which they occur, they show none of the symmetrical arrangement appertaining to lodes, and must consequently be regarded as epigenetic. They are almost invariably associated with eruptive rocks, such as diabases and their derivative tuffs or quartz-porphyries and their derivative tuffs. Two categories of such deposits may be distinguished, the slate or schist-type (to which those here described belong) and the limestone-type.

L. L. B.

THE ROSSITZ COAL-FIELD, MORAVIA, AUSTRIA.

Die Tektonik des Steinkohlengebietes von Rossitz und der Ostrand des böhmischen Grundgebirges. By FRANZ E. SUESS. *Jahrbuch der kaiserlich-königlichen geologischen Reichsanstalt,* 1907, *vol. lvii., pages* 793-834, *with* 2 *figures in the text and* 2 *plates.*

There is a strip of the Rothliegende formation which extends for some 93 miles from Senftenberg in Bohemia, through Mährisch-Trübau, Boskowitz, and Rossitz, as far as Mährisch-Kromau, and its tectonic importance, as demarcating the boundary between the ancient crystalline schists of the Bohemian massif on the west and the older Palæozoic plications of the Sudetic ranges with the Brünn intrusive mass on the east, did not escape the earlier observers. Recently, Dr. Tietze has applied to this long and narrow *graben* or *fosse* the appellation of the "Boskowitz rift," drawing

attention to its connexion with those post-Cretaceous disturbances which resulted in the upheaval of the Sudetic ranges and the Riesengebirge, and also to the bifurcation of the rift northwards into two parallel *gräben* or *fosses*. In the present memoir the author deals almost exclusively with the tectonic details of the southern portion of the rift, and with the extension of the main tectonic features beyond its southern termination as far as the neighbourhood of Znaim.

By far the greater portion of the Boskowitz rift is filled up with the red and grey sandstones, and thinly-bedded shales and occasional conglomerates, which are all assignable to the Rothliegende; but from Rziczan near Rossitz southwards these are succeeded by the underlying coal-bearing sandstones and enormous masses of conglomerates, determined as being of Coal-measure age. Dr. Katzer, in a recent review of the flora of the Rossitz seams, has found undoubted Permian as well as Upper Coal-measure plants therein; indeed, the occurrence of *Walchia pinniformis* in the middle seam predisposed him to claim the entire formation as Permian. But Dr. Weithofer points out that the premature occurrence of some isolated Permian plants hardly justifies so drastic a conclusion, and holds that the seams belong to the uppermost Coal-measures or Radowitz Group; he adds that the true Permian flora only begins above the roof of the topmost coal-seam. Some authors have included the coal-bearing horizons and the Rothliegende in one formation as Permo-Carboniferous, and although Dr. F. E. Suess, following the late Dionys Stur and Dr. Weithofer, separates the coal-bearing group as Upper Carboniferous from the Rothliegende, he retains an open mind as to the true stratigraphical relationship of these measures. He regards them as largely of desertic origin, drawing a comparison between them and the coal-basins of the Central Plateau of France, down to the minutest details of sedimentation. The basement-conglomerates attain a thickness exceeding 660 feet; they are overlain by sandstones (often extremely felspathic) with intercalated thinly-bedded shales, and some 70 feet up in these is the third or lowest coal-seam, hardly workable, but very rich in plant-remains. This is overlain by about 165 feet of multi-coloured sandstones with inter-

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horizons of bituminous shale, one of which is especially rich in fish-remains, and in reality fall naturally into the same group as the coal-bearing rocks.

With regard to the possible opening-up of the main seam in the as yet unexplored portions of the area, the prospects in the south, at all events, are not hopeful. Nor are they more favourable in the east; the most probable extension of the coalfield may be looked for on the north, under the Rothliegende strata at Rziczan, but even here the decrease in the thickness of both the seams and the basement-beds north of Segengottes rather implies approximation to the rim of the old basin. L. L. B.

THE AURIFEROUS ROCKS OF TRANSYLVANIA.

Das Goldvorkommen im Siebenbürgischen Erzgebirge und sein Verhältniss zum Nebengestein der Gänge. By M. VON PÁLFY. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 144-148, *with* 3 *figures in the text.*

One of the main problems to which the author addresses himself in this paper is the question whether the country-rock is a determining factor in the infilling of lodes which yield the precious metals, and, if so, in what manner its determining influence is exhibited.

Premising that, until recently, all the lodes in the Transylvanian Erzgebirge had been regarded as the infilling of contraction-fissures which supervened in the mass of molten eruptive rock in process of cooling, he asserts most positively that his detailed investigations now prove these fissures to be in all cases of tectonic origin, and their strike coincides with the two main directions of those lines of tectonic movement that can be traced throughout the mountain-*massif* above-mentioned.

As to the source of the precious metals in the lodes, it must be sought in the hundreds of volcanic necks which are scattered over this Erzgebirge. In the later phases of vulcanicity, the upwelling gases and vapours undoubtedly precipitated the metallic particles with which they were charged in the vicinity of these necks. The hypothesis, according to which the precious metals were already existing in an extremely-fine state of division in the eruptive rocks cannot, for several reasons, be sustained. The lodes are only auriferous down to certain (it is true, variable) depths; but the gold does not occur even as low down as sea-level, whereas, if the above-mentioned hypothesis were true, enrichment ought to keep pace with depth—or at least the lodes ought to be gold-bearing much deeper down than is the case. It will be observed that, generally speaking, the precious metals in the Transylvanian Erzgebirge do not occur actually within the volcanic necks, but mostly along their margins or in the country-rock immediately adjacent thereto. As the distance from a volcanic neck increases, the amount of precious metal in the lodes decreases, more or less rapidly. The author's view is based on an examination of the rocks exposed in every single mine in the district, and he holds that it is now possible to say with absolute certainty at what localities precious metals may be looked for—bearing in mind, of course, the possibility that the vapours or gases emanating from the "necks" in the moribund phase of vulcanicity did not in every case carry particles of precious metal.

At Nagyág, the lodes course partly through a neck, partly through its capping of soft decomposed lava and Mediterranean (Tertiary) deposits. The precious metals are exclusively obtained from this "cover" of decomposed lava, and only in the vicinity of the neck. In all the other

localities cited, stress is repeatedly laid upon the fact that it is the vicinity of the neck which is important, rather than the nature of the country-rocks—these include andesites, dacites, liparites, lava-flows, tuffs, breccias, melaphyres, Carpathian sandstones, and Mediterranean shales; and at Ottenbánya crystalline schists and limestones. L. L. B.

NATIVE COPPER IN THE FÆRÖE BASALTS.

Über das Vorkommen von gediegenem Kupfer in den Trappbasalten der Faröerinseln By F. CORNU. *Zeitschrift für praktische Geologie,* 1907, *vol. xv., page* 321-323.

After a brief conspectus of the literature of the subject, the occurrences of native copper having been observed as far back as the latter half of the seventeenth century, the author gives a general account of the geology of the Færöe (Islands) which he visited in the summer of 1907. This is far from complicated, as that remote archipelago is built up of great basalt-flows of early Tertiary age, among which are intercalated thin bands of red-burnt ash. On Suderöe and Myggenaes there occur also some interbanded layers of clay with coal-seams. The general dip is south-easterly.

With regard to native copper, the author examined the localities on Naalsöe, an island lying opposite Thorshavn, the capital of the Færöe. The inhabitants are well aware of the occurrence of the metal, and masses now and then found on the beach have been worked up by native artificers. But the widespread belief among them that the copper is auriferous and that gold may yet be discovered on Naalsöe is absolutely unfounded. The copper itself is, on the whole, so sparsely distributed in the basalts that no encouragement can be given to the idea of working it for commercial purposes. The metal is found in druses, associated with various zeolites which appear to have crystallized out later than it.

South-east of Trangisvaag on Suderöe, on the way to Frodeböenyper, the author observed at the outcrop of a coal-seam on the shore at Frodeböe a compact black "trap-basalt" forming the immediate roof of the seam, and containing native copper in large zeolitic amygdules. The copper [redacted]

THE SEARCH FOR COAL IN FRANCHE-COMTÉ, EASTERN FRANCE.

Les Recherches de Houille en Franche-Comté : le Massif de Saulnot et sa Bordure. By EUGÈNE FOURNIER. *Bulletin de la Société Géologique de France, series* 4, 1907, *vol. vii., pages* 517-524, *with* 1 *figure in the text.*

South of the Trias which overlaps the Permian strata forming the southern limit of the Ronchamp coal-basin, there is a small outcrop of metamorphic Devonian schists to which the author gives the appellation of the Saulnot *massif*: against it abut, south of Chenebier, the Culm-measures. Now, as similar Devonian and Culm rocks appear on the northern margin of the Ronchamp coal-basin at the southern extremity of the Vosges, it was hoped that borings put down in the Permo-Triassic area north of the Saulnot massif would strike at some unknown depth the presumed southerly extension of that coal-basin. The author was called upon in 1902 to give his opinion as to the probable results of a borehole put down at Lomont: various geologists had asserted that the site could not have been worse chosen, and that the Devonian would be reached at a depth of 1,300 feet. The author, however, rightly predicted the occurrence of coal-seams somewhere between 3,440 and 3,600 feet. The first venules of coal were struck at 3,365 feet; and at a depth of 3,575 feet, the bore commenced passing through a group of coal-seams, some of which were respectively 4 feet, $5\frac{1}{2}$ feet, and 6 feet thick (the last-mentioned seam at the depth of 3,610 feet). About $22\frac{1}{2}$ feet lower down the boring-tool remained fast in black shales, the character of which indicated the neighbourhood of another coal-seam group of Stephanian age.

The author assigns the reasons for which he considered that any attempt to strike coal at a shallower depth near the Saulnot *massif* was foredoomed to failure, and the untoward results of the Courmont boring, stopped at a depth of 3,503 feet, confirmed his forebodings. Down to 2,952 feet eruptive rocks of Permian and possibly Upper Coal-measure age were passed through: in all, the thickness of the Coal-measures passed through was estimated at 500 feet, but not a single coal-seam was struck, and the boring was stopped in green porphyritic tuffs (supposedly of Culm age). It is held that the search for coal should be continued at a distance of at least 2 miles north of the Saulnot *massif*, in the neighbourhood of Lomont and north of Faymont, but that investigations should not be pursued too far to the eastward. The coal-basin would appear to deepen and increase in dimensions westward; but researches conducted too far in that direction also would be of little avail, as the coal would be struck at an impracticable depth for mining operations. Thus a boring put down at Frotey-les-Lure continued in the Permian down to a depth of 4,100 feet. The workable seams of the Lomont basin, for which a concession was granted in 1904, are estimated to extend over a length of $3\frac{3}{4}$ miles, parallel to the margin of the Saulnot *massif*, and over a breadth of not less than 2 miles. They will be worked between the depths of 3,440 and 3,770 feet, and in thickness and quality are comparable with those of Ronchamp. A deposit of malachite and azurite was discovered in the course of the boring operations, at two points in the Valettes ravine near Courmont, among arkoses and microgranulitic tuffs of Lower Permian age. The deposit is undoubtedly sedimentary and of lenticular character, and in the author's view exploration-work upon it has been abandoned too hastily, as it is a certain indication of the existence in depth of a lode of sulphidic ores which might repay working.

South of the Saulnot *massif* the stratigraphical succession is absolutely normal: a boring put down at Chevret was stopped in the Muschelkalk at a depth of 1,476 feet. If Coal-measures occur on that side of the anticline, they cannot be struck at a depth less than 3,610 feet from the surface.

L. L. B.

COATQUIDAN IRON-ORES, BRITANNY.

Sur le Minerai de Fer de Coatquidan. By F. Kerforne. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences,* 1908, *vol. cxlvi., pages* 1226-1227.

The Coatquidan iron-ore deposit, in the department of Morbihan, was first worked in 1825, but has now been abandoned for some little time. Its output was used in the iron-works of Paimpont. The deposit would appear to lie at a geological horizon marking the division between the Cambrian pink grits and claret-coloured shales, and the Ordovician white grits, practically at the base of the Armorican Grit. It dips very slightly north-westwards, and in thickness occasionally attains a maximum of 6½ feet. The ore, a red hæmatite, not seldom earthy, but most frequently granular, appears to be built up of flattened irregular granules with a black patina, immersed in a red ore of finer texture containing a fairly considerable amount of minute grains of quartz. In places this particularity is so exaggerated that the deposit presents rounded nodules of hæmatite of extremely irregular shape immersed in a ferruginous mass with big quartz-grains, forming, in fact, a sort of conglomerate. The Coatquidan ore differs, then, in character, from most of the known iron-ores of Britanny and Normandy, the only deposit that is at all similar to it occurring at Caden, farther south.

L. L. B.

ORDOVICIAN IRON-ORES OF LOWER NORMANDY.

Note sur le Minerai de Fer silurien de Basse-Normandie. By Ch. E. Heurteau. *Annales des Mines, series* 10, 1907, *vol. xi., pages* 613-668, *with* 7 *figures in the text and* 3 *plates.*

[redacted]

of the present day gives no reliable clue; the ancient hydrostatic levels require to be traced out (if that were possible), in order to determine the limiting-level of the action which in ages gone by oxidized the carbonate to hæmatite. These Ordovician ores have been struck, and are worked along four synclines, which are, proceeding from north to south: (1) the syncline of St. André and May-sur-Orne; (2) the Perrières-Barbery syncline, passing through La Brèche au Diable; (3) the Falaise syncline, passing through St. Rémy and Jurques; and (4) the La Motte Forest-Mortain syncline, with which connects an important ramification extending northwards to La Ferrière-aux-Étangs and Halouze.

The workings of the May mine, on the southern rim of the first syncline, have followed up the ore-body for more than a mile and a quarter to the east of the river Orne; although the ore-body approaches 20 feet in thickness, it is too highly silicified to allow of more than 6½ feet being worked, and that near the foot-wall. As deep as the workings have gone, that is, down to 115 feet below the river-level, the ore is hæmatized. The silica often invades the lower portion of the ore-body in such a fashion that it can be regarded at its base as richly metalliferous only in irregular patches separated by siliceous areas. The dip varies from 45 to 50 degrees. At St. André, still on the right bank of the Orne, but on the northern rim of the syncline, the ore-body seems to be well nigh vertical, with, in places, a reversed northerly dip. As at May, it is some 20 feet thick, the richer portion, near the footwall, measuring from 8¼ to 10 feet in thickness, the remainder being practically non-payable ore: workings pushed some yards below the river-level here have disclosed a diminution in thickness of the hæmatite, the rest of the ore being then unmistakably a carbonate. The parallel outcrops of May and St. André, some 1,420 yards apart, are concealed by the Jurassic rocks, and are faulted by a few unimportant dislocations.

The eastern limit of the Perrières-Barbery syncline follows a normal course and is well known, but its western boundary is masked by the Clay-with-Flints of the Forest of Cinglais. Two rivers (the Laize and the Laizon), entering the basin by deep gorges cut in the Armorican Grit on its southern margin, reveal therein the ore-body, the outcrop of which is smothered on the plateau by 70 to 130 feet of Jurassic beds. The ore-deposit lies in the *Calymene*-slates, some 150 feet above the Armorican Grit, and is mineralized over a thickness of 16½ to 20 feet; but its percentage in iron and its general character are somewhat irregular. The hæmatized portions lie near the footwall, rarely exceeding 6½ feet in thickness, and averaging 5 feet. Frequently the hæmatite gives place to grit or to clay, and indeed only occurs immediately beneath the Jurassic covering-rocks: 60 or 70 feet lower down, it appears to be everywhere replaced by carbonated ore, and occasionally the carbonates reach up to the Jurassic. In point of fact, the deposit may be shortly described as a basin of carbonate, the margins of which are irregularly hæmatized, the hæmatite being generally of a rather earthy nature. The mean dip is 50 degrees; borings, at the time of writing, were in progress, with the view of determining whether the ore-deposit flattens out in depth.

The Falaise-St. Rémy-Jurques syncline is of a more complicated structure than the two just described: the *Calymene* Slates are, in places, unrecognizable, and the ore-body is not always met with just where it might be expected. What with oscillations of the crests of a double syncline, and what with numerous longitudinal and transverse faults, the Ordovician

basin has been cut up into, as it were, a series of islets, or separate inliers. In the St. Rémy mines the ore-deposit is found at the junction of the Armorican Grit and the *Calymene* Slates: it is entirely hæmatized, its percentage of iron (52 to 53, the highest in the region) is very constant, and its thickness (also extremely regular) ranges between 8½ and 9 feet. Exploration-work farther west, on the Montpinçon hill, has not yet revealed there the existence of a workable ore-deposit: the hæmatite can be followed for a few yards, is then lost, and re-appears from place to place, varying in thickness from a few inches to 5 feet. At Jurques, a band of carbonated ore, dipping from 55 to 68 degrees northward, 3 to 4 feet thick, has been struck just above the Armorican Grit.

The Bagnoles-Mortain syncline ramifies into two in the neighbourhood of the Mont-en-Gérome. With a few local exceptions, the ore-band occurs at the junction with the Armorican Grit, and is hæmatized in places. In the Forest of Halouze, the continuous Ordovician outcrop is traceable for about 2½ miles: the ore-body here is almost vertical and exceeds 13 feet in thickness.

The hæmatized ores in this region have been worked for many generations, and the ancient workings have served as useful indicators for the modern concessionaires. The first of the more recent concessions (St. Rémy) dates from 1875, and was enlarged in 1884 by the Halouze concession; but it was not until the metallurgical "boom" of 1900 or thereabouts that exploration-work was directed to the less accessible portions of this great series of ore-deposits. Since 1895 the annual output from the St. Rémy mines has ranged between 95,000 and 110,000 metric tons. The pillar-system of working, leaving 9 per cent. of the ore in place, has had to be abandoned as too dangerous, and under present conditions from 15 to 16 per cent. of the ore is left (some, at least, of which may be got later). The stuff is brought down by means of dynamite. The St. André mine showed in 1906 an output of 27,971 tons; but this hardly represents its full capabilities, as perhaps the richest part of the ore-body there has still to be explored. The May mine yielded 75,000 tons in 1906: the ore [redacted]

4·5 of lime and magnesia, 4·3 of alumina, and the loss on ignition is 26·6. The percentage of iron at La Ferrière tends apparently to increase as the workings reach deeper-lying horizons, and often exceeds 51; the lime also increases slightly with the depth. The cost-price of the hæmatite delivered into the railway-trucks is reckoned by the author as 5 francs or 4s. 2d. per metric ton; that of the crude carbonate as about 2s. 9d.; and that of the calcined carbonate as about 5s.

The ores are to a large extent shipped from Caen to Great Britain and Germany; the author devotes an entire chapter to the consideration of the manner in which this export is effected, and points out incidentally how the Rotterdam shipowners have contrived to monopolize the sale of iron-ore in Westphalia and have even extended their operations to the British market. Practically the only variety of Lower Normandy ore now utilized in the north of France is the calcined carbonate, got from concessions belonging to the Denain and Anzin Steelworks Company. L. L. B.

BROWN-COAL DEPOSITS OF THE HOHER WESTERWALD, GERMANY.

Die Braunkohlenlagerstätten des Hohen Westerwaldes, unter besonderer Berücksichtigung ihrer wirtschaftlichen Verhältnisse. By F. FREISE. *Zeitschrift für praktische Geologie*, 1908, *vol. xvi., pages* 225-237.

By a singular concatenation of circumstances these deposits, which, considering their extent, their quality, and the availability near at hand of natural resources favouring mining operations, should under ordinary conditions, have given rise to an active mineral-industry on the grand scale, have been until quite recently worked only just enough to supply a purely local demand. The concessions were split up among small or unenterprizing capitalists; transport-facilities were defective; and markets ready to absorb a large output were the less easy to find, in view of the enormous recent development of the German bituminous coal-industry and its consequent overwhelming competition with the brown-coal industry. Many of these difficulties have now, however, been overcome, and the author foresees a brilliant future for the mining-field which he describes.

The Hoher Westerwald is a table-land rising from a minimum level of 720 to a maximum level of 2,200 feet above the sea, dropping rapidly towards the Heller valley on the north, and towards the Dill valley on the east, but sloping very gradually southwards and westwards to the Rhine and the Lahn. The rocks of the district include, besides the lignite- or brown-coal seams, clays, quartzites, sands, quartz-gravels, conglomerates, tuffs, pumiceous rocks, and basalts. The last-named are mostly plagioclase-basalts, rarely nephelinic: they extend for more than 18½ miles from north to south, and for about 22 miles from east to west. Two main flows are distinguishable: the older, lying below the brown-coal group, is known as the "floor-basalt," and the younger, coming above that group, is known as the "roof-basalt." The clays are perhaps the most considerably developed of the sedimentary deposits, both above and below the brown-coal seams, and thin layers of them are interbanded with these. In several localities the clays are indurated into a tough material with conchoidal fracture; and in some few localities, where they have preserved their full plasticity, and contain but little iron-oxide and coaly matter, they are of industrial value. The brown coals or lignites have a brown to a pitch-black coloration, flaky to smooth fracture, and are rather splintery. Their percentage composition, taking the mean of forty analyses, is as follows:—Carbon, 58 to

70; hydrogen, 5 to 6½; oxygen and nitrogen, 11 to 20; hygroscopic water, 32 to 42; ash, 2 to 6. On drying in atmospheric air, the mineral loses from 20 to 22 per cent. of water, and flakes away easily. Its heating power, when freed from water, ranges from 7,100 to 7,250 calories; and in this respect, therefore, it is almost comparable with the best bituminous coals. The author made coke from it experimentally, and found that picked samples of the best grade of the mineral yielded 55·38 per cent. of coke, fairly compact and tough. The Westerwald lignites by themselves cannot be used for the production of illuminating gas, but they form an admirable adjunct to the ordinary gas-coal when mixed with it for gas-manufacturing purposes. Plant-remains, including maple, oak, alder, poplar, willow, elm, laurel, etc., are abundant; but the sole animal-organism found in the brown-coal seams is represented by the scales of *Leuciscus papyraceus*. On the whole, these deposits occupy a deep basin hollowed out in the Devonian rocks, striking north-east and south-west, and measuring in its greatest breadth (from Marienberg to Mengerskirchen) about 11 miles. The comparatively steep dip of the underlying basalt-conglomerates leads irresistibly to the inference that the filling-up of this basin was accomplished at repeated intervals; the successive layers of deposition are seen to become gradually flatter, until at the horizon of the brown-coal seams they are all but horizontal. The conglomerates lessen in coarseness upwards, until just below the seams they pass into hard sandy clays among which are sparsely scattered occasional fragments of basalt. The strata of the brown-coal group, partly as a result of the basalt-outpourings (which continued, as we have seen, after the deposition of the lignitic seams), and partly as a result of the disappearence of the clays and the continuous sagging of the basin, are broken up by enormous fissures into "fault-blocks" of varying mass. Most of the underground workings that have been systematically explored show from three to six seams, ranging in thickness from something over a couple of inches to 13 feet or so. Generally two seams alone, and those the lowest in the series, can be regarded as workable. The Wilhelm mine at Bach is unique in having proved three workable seams.

The mining field comprises 130 concessions, covering an area of 90 square [redacted]

probable amount of brown-coal actually available in that area: he himself says that, in the absence of detailed and systematic exploration-work, his figure of 982,041,720 cubic feet (or 20,237,970 tons, according to the weight stated for a cubic metre of the mineral at an earlier stage of the paper), must be accepted with due reserve. L. L. B.

POSSIBLE NEW COAL-FIELDS IN THE ERZGEBIRGE REGION, GERMANY.

Über die Möglichkeit der Aufschliessung neuer Steinkohlenfelder im erzgebirgischen Becken. By C. Gäbert. *Zeitschrift für praktische Geologie,* 1908, *vol. xvi., pages* 114-119, *with a map in the text.*

Coal-mining in this region is principally centred in the Zwickau-Bockwa-Oberhohndorf district and in the Lugau-Würschnitz-Œlsnitz district; in the former, the coal-seams are now all but worked out, and in the latter the amount of coal in sight is diminishing at so fast a rate that the kingdom of Saxony will cease to occupy a place in the list of coal-producing countries, unless fresh coal-fields are meanwhile opened up. For several years strenuous endeavours in this direction have been made, but have met so far with almost negative results. Details are now published, for the first time, of three deep borings put down during the years 1899-1905, in the neighbourhood of Oberzschocken, in the presumed south-western extension of the Würschnitz coal-field. The deepest, going down to 3,575 feet below the surface, passed through 370 feet of Coal-measures with five thin seams (ranging from 2¼ to 34 inches in thickness); the second, terminating in the fundamental rocks at the depth of 2,395 feet, passed through 210 feet of completely barren Coal-measures; and the third, terminating similarly in the fundamental rocks at the depth of 2,318 feet, passed through 103 feet of Coal-measures yielding mere traces of coal. These results were the more disappointing that the second and third borings are respectively distant but two-thirds of a mile, and barely one mile from the Œlsnitz-Vereinsglück collieries, where a seam from 10 to 16 feet in thickness is being worked; and the opinion has been expressed that these borings must have pitched precisely on faults or nip-outs, passing (very likely) quite close to workable coal-seams. With regard to the first boring, situated 1¼ miles south-west of the now abandoned Frischglück shaft, favourable results were perhaps hardly to be expected, as in that shaft, out of a total depth of 2,752 feet, only 295 feet can be assigned to the Coal-measures, with four seams ranging in thickness from 4¼ to 40 inches. Thus, at two points at great depths within an extensive coal-basin, we find that seams which are of considerable thickness towards the southern and eastern margins, wedge out towards the centre of the basin, in which direction they show a constant but low dip. The advisability seems indicated of further boring operations, in the Niederzschocken flats, south-west of the above-mentioned second and third borings, and not too far from the rim of the coal-basin.

In the summer of 1907 a boring was put down in the Neukirchen plain, north-east of Lugau, striking the Coal-measures at the depth of 1,027 feet, and passing out of them into the Cambrian slates 174 feet lower down (that is, at 1,201 feet). A seam of very pure coal about 20 inches thick was found in this boring, as well as venules of coal at various horizons. The stratigraphical details of this boring, when coupled with the results, only recently rediscovered, of a boring put down north-east of

Leukersdorf as long ago as 1863, indicate that it is in the Leukersdorf-Neukirchen area that those who are looking for an extension of the Lugau coal-field should pursue their investigations. L. L. B.

THE GOVERNMENT COLLIERIES IN THE SAARE DISTRICT, GERMANY.

Der Steinkohlenbergbau des preussischen Staates im Saare-Reviere: Reisebericht. By FRIEDRICH OKORN. *Berg- und Hüttenmännisches Jahrbuch der K. k. montanistischen Hochschulen zu Leoben und Přibram*, 1907, *vol. lv., pages* 1-80, *with* 3 *figures in the text and* 1 *map.*

The Saarbrücken coal-basin fills up a depression which started somewhere about the end of the Lower Carboniferous Epoch, probably along an ancient line of disturbance, and, gradually sagging until about the end of Lower Rothliegende time, provided an area wherein the terrestrial and freshwater formations constituting the productive Coal-measures could be laid down. The general strike of these measures (which form a monoclinal fold) is from north-east to south-west, the dip is north-westerly, diminishing quickly westwards from 40° at the south-eastern margin to 5°. The occurrence of coal-seams has been proved over a distance of 56 miles, from the Potzberg in the Bavarian Palatinate, through St. Avold, Falkenberg, Bolchen, and Busendorf in Lorraine, and thence across the frontier into French territory. The breadth of the basin varies between 18 and 25 miles in the north-east, and attains 43½ miles in the south-west. On the south-east Archæan gneisses and granites appear to underlie the coal-basin, while on the north-west the Lower Devonian conglomerates, mottled slates, micaceous and quartzose sandstones and clay-slates, form the marginal rocks. At no point have the strata which immediately underlie the Coal-measures been exposed. The succession of the Saarbrücken Coal-measures, averaging a total thickness of 14,750 feet, is, in descending order, as follows:—

Upper Ottweiler Beds.—Grey, seldom red, shales, sandstones and conglomerates. Breitenbach or Hausbrand coal-seam.
Middle Ottweiler Beds.—Red and grey sandstones and shales,

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including 4½ feet of partings); and the Henry seam of the Klein Rosseln colliery (26½ to 29½ feet, split up into twelve or sixteen bands, the thickness of pure coal ranging from 19½ to 21½ feet). The immediate roof of the seams is *brandschiefer* (bituminous slate), and the immediate floor always ordinary shale. The partings are usually *brandschiefer* shales, occasionally clay, ironstone or clay-stone; thick partings pass into sandstone. The uppermost of the seams hitherto worked in the Saare district is the Grenzkohlen (or Breitenbach or Hausbrand) seam, which has been traced from Dirmingen (in the north-eastern part of the field) through Mainzweiler to Breitenbach and Steinbach in the Palatinate, over a length of 18½ miles or more. The Hirtel seams, lying 1,300 feet deeper down, and proved over an extent of 10 miles from Labach to Illingen, consisting of an assemblage of narrow bands of impure coal (averaging a total thickness of 1½ to 3 feet) have not (so far) repaid working. Some 1,300 feet below these comes the Schwalbach-Lummerschied seam, and 500 feet below this again the Wahlschied seam, which are the highest seams worked in the Prussian State collieries. Of far greater importance are the seams of the upper and lower long-flame coal-groups, the lie and composition of which have been proved along the strike for a distance of 30 miles within Prussian territory, and over a breadth of nearly 2 miles. The upper group at its maximum (Reden colliery) includes fifteen to twenty workable seams with a total thickness of 78¾ feet of coal; the lower group includes only two or three workable seams, with a total thickness of 11½ to 14¾ feet of coal. The measures intervening between the long-flame and the bituminous coal-groups contain a few seams, most of which are less than 12 inches thick; nevertheless, they are worked at some collieries, and are likely to be more extensively worked as the thicker seams approach the limit of exhaustion. The bituminous coal-group, including well over a hundred seams with a total thickness of 115 to 135 feet of coal, suitable some for coking, some for gas-manufacture, and some for boiler-firing purposes, is perhaps the most important division of the entire series. Below this comes the Rotheller group, worked only at the Bavarian Government colliery of St. Ingbert; it contains about 65½ feet of pure coal, distributed among 70 or 80 seams, few of which attain a thickness of 2½ feet, the majority being less than 12 inches thick. The Coal-measures are much disturbed by faulting, the most considerable fault being that known as the Main Southern Fault, which indeed constitutes the southern boundary of the coalfield. The amount of coal in sight in the 265,000 acres reserved by the Prussian Government is estimated (down to a depth of 3,000 feet) at 3,660,362,000 metric tons; that in sight in concessions appertaining to Bavaria and Lorraine (both governmental and non-governmental) is estimated to amount to 156,880,000 tons. But no estimate can be formed in regard to the newly-discovered enormous extension of the coalfield in Lorraine. The duration of the coal-supply in the area reserved by the Prussian State is reckoned to extend to five hundred years from now.

There are twenty-four collieries at work, most of which are independent one of the other in regard to haulage, ventilation, and pumping. The districts assigned to each colliery have generally natural boundaries, in the shape of faults. The depth of the workings increases on the whole from south to north, in accordance with the dip of the measures; the deepest Government shaft at present is that of the Louisenthal colliery (2,240 feet). The total heights of the workings, from bottom-level to top, are conditioned by the same circumstances as those which determine the area to be worked, that is, largely by the lie and number of the seams, the total height being generally greater in the long-flame coal-group than in the richer bituminous coal-group. Three-

quarters of the material necessary for packing is got on the spot, and a very small amount is sent down from bank or "washed in" (*einspülung* method). The recently extended use of packing has greatly contributed to the diminution of accidents by falls of stone or coal in the Saare basin. The "washed-in" packing consists of broken-up clinkers, waste from the heapstead, and sand. About 75 fans of various types (22 Guibal, 22 Pelzer, 12 Kley, 6 Capell, etc.) are in use for ventilating the pits, the first-named being perhaps the oldest, while the very newest fans set up are four of the Pelzer type and three of the Rateau. The evolution of fire-damp in the Saare collieries appears to follow a regular course, and is more marked in the bituminous coal-groups than in the long-flame; it also increases with the depth from the surface. There is a dangerous amount of dust in the deeper collieries, especially in the Eischbach valley. Wolf benzine-lamps, with generally a single gauze, possess a practical monopoly in this coal-field; recently, the cylinders have been made of a specially hard glass by a Jena firm, and although this increases the cost of the lamp by 40 per cent., its life is prolonged by 83 per cent. Friction-igniters have come recently into extended use, and the lamps are locked magnetically, or are provided with the "twin-bolt" or "twin-rivet" lock. Pit-fires are now of rare occurrence. All colliery-officials and a suitable number of pitmen are trained in the use of rescue-apparatus, about seven permanent rescue-companies to the number of 200 men being organized. In 1905, the rescue-appliances available included 41 of the Dræger type, 28 of the Giersberg, 29 Walcher-Gärtner, 12 Neupert pneumatophores, 36 anti-smoke masks of various types, and 170 electric accumulator-lamps, also of various types.

A detailed description is given of the methods of haulage, pumping (the inflow of water in the Saare collieries is comparatively unimportant), steam-raising, air-compressing, etc. All the coal that is brought to bank, or nearly all of it, has to undergo mechanical sorting and washing before it is marketable: these processes are described at great length. About 20 per cent. of the output is converted into coke, the amount got from the undried coal (reckoned at 100) being 53 or 57, as compared with 65 or 70 per cent. in the case of the Westphalian bituminous coal. The coke as sold yields about 12 per cent. of ash. The various processes of coking, with and without bye-products, and the

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A lengthy description is then given of the pisolitic clay-ironstones which occur among the Lower Jurassic yellow sandstones around Aalen and Geislingen, in the Kocher and Fils valleys respectively. In the first-mentioned district about ten bands of ironstone have been proved, their combined thickness amounting to 15¼ feet; while in the Fils valley this amount apparently shrinks to, at most, 9 feet, though mining operations are at all events facilitated by the concentration of the ore into a single band instead of its being distributed among ten bands. The above-mentioned sandstones form the conspicuous capping of the *Opalinus*-clays, and are said, in their present condition, to be the outcome of a process of leaching by surface-waters: in this process, all the lime-constituents have disappeared, and so a lime-flux has to be supplied when the ores are being smelted—a not inconsiderable item of expenditure. The pisolitic ironstone consists of small rounded granules of extraordinarily equal size (not unlike very small shot) with a clay-cement; the best grade of ore is of a dark chestnut-brown, while the lower grades have a lighter tinge, drawing more towards copper-red. The specific gravity of the undried mineral is 2·68. Irregularly-shaped quartz-granules are intermingled with the pisolitic ore, occasionally in such numbers as to destroy the industrial value of those portions of the ore-body. Fissures in the ore-body, infilled or coated with calcite, or, as the case may be, with calc-sinter, are of frequent occurrence; and the miners find these fissures helpful in working out the masses of ore.

On the southern flank of the Swabian Alb, the Jurassic rocks are mantled over by widespread Tertiary deposits; in pockets and pipes which go down into the Jurassic rocks, pisolitic ores of Tertiary age were at one time actively worked. It may be gathered that, on the whole, iron-ore mining has reached a very low ebb in the kingdom of Württemberg, since the figures tabulated by the author put the total production for the year 1906 at 7,872 tons, the number of workpeople employed being only 41. As to the amount of ore still in sight, he states that accurate estimates can only be formed in regard to the Wasseralfingen-Aalen district (4,943,400,000 cubic feet estimated). Although deep-level mining would seem hopeless in the case of ores which nearer the outcrop have come to be considered as barely workable, it is pointed out that deeper down their mineralogical composition is likely to be more advantageous, inasmuch as the lime will not have been leached out of them; and, if ever there be a shortage in the world's supplies of iron-ore, many will be glad to have recourse to the great natural storehouse of that ore which lies beneath the surface in Württemberg.

Borings for coal in that region have been unsuccessful, and great improvements in the navigable rivers and canals are necessary in order to permit of the easy transport of coal in bulk with (conceivably in the future) return cargoes of iron. In 1907 there was but one ironworks producing pig-iron left in activity in the kingdom of Württemberg, employing 25 workpeople; on the other hand there are several important works turning out machinery, etc., which have their own foundries attached to them. L. L. B.

AGE OF THE SIEGERLAND IRON-ORES, GERMANY.

Beitrag zur Kenntniss vom Alter der Siegerländer Erzgänge. By H. LOTZ. *Zeitschrift für praktische Geologie*, 1907, *vol. xv., pages* 251-253, *with* 1 *figure in the text.*

The Glaskopf mine at Briersdorf was opened up in two systems of highly-disturbed, thrust, and fissured lodes, the general effect of such disturbances being to intensify the economic disadvantages that attended mining operations

and finally to cause the abandonment thereof. The infilling of the lodes is typical for the Siegerland district: spathose iron-ore is accompanied by chalcopyrite (either in isolated crystals or intergrown in thick masses with the iron-ore); ordinary pyrite is of less frequent occurrence. Diabase, varying in colour from very dark-green to a dirty yellow, was first struck at the 574-foot level, and later on at various lower levels; it evidently forms a dyke, some 16½ to 33 feet broad, dipping 60 degrees westwards. It cuts the Vorsichter lode at an acute angle, and the effect of its intrusion is to metamorphose by contact the spathic iron-ore into magnetite over a certain distance to the north. This magnetite has yielded 54 per cent. of metallic iron, as compared with the 46 to 48 per cent. yielded by the ordinary spathic ore of the mine (when roasted). The contact-metamorphism is said to extend laterally for 23 to 26 feet. On the south, after getting through the diabase, the miners found the lode very full of quartz and practically unworkable.

The Siegerland metalliferous lodes are in part, if not all, of ancient origin, dating back at least to Devonian times. It may be noted that the earliest diabases known in the Rhenish slate-area are of Upper Devonian age, and here there is proof that the diabases have invaded and altered pre-existing lodes. It seems clear that the Siegerland lodes were originally mineralized with iron-ore, and that silicification and pyritization (with chalcopyrite and ordinary pyrite) are phenomena of later date, possibly contemporaneous with, or subsequent to, the diabasic intrusions. Some of the disturbances to which the metalliferous lodes have been subjected must be assigned to the great orographic plication which took place during the Carboniferous Period.

L. L. B.

IRON- AND MANGANESE-ORE DEPOSITS OF OBERROSBACH, GERMANY.

Über die Genesis der Eisen- und Manganerzvorkommen bei Oberrosbach im Taunus. By — **Bodifée.** *Zeitschrift für praktische Geologie,* **1907**, *vol. xv., page* **309-316**, *with* **6** *figures in the text.*

Among the iron- and manganese ore-deposits which have of late years attracted increasing attention in the Grand Duchy of Hesse, next to the

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and manganese-ores were chiefly concentrated in the hollows and "pockets of this surface, and therefore the ore-body would be more correctly described as a series of "nests" than as a bedded deposit.

The "new" deposit has been worked for the last 4 years; it strikes north and south, and has an easterly dip averaging 45 degrees. A number of shafts have been sunk, to a maximum depth of 300 feet, and have shown that the ore-body varies in thickness between 50 and 100 feet. It has all the characteristics of a truly bedded deposit. The dolomitized limestone, the invariable carrier of the ore in the "old" and in all the other Hessian deposits, has not been struck in these shafts at any point, despite the most sedulous investigation: either it lies at a far greater depth, or it has swerved considerably south-eastwards—the latter supposition seems to be confirmed by certain trial-borings put down within the last few years. The limestone has indeed been encountered therein at a depth of 220 feet, and (precisely as in the case of the "old" deposit) proves to be overlain by a band of crumbly ore of variable thickness; while it gives evidence of dolomitization for some 13 to 16 feet, as compared with 65 to 90 feet in the neighbourhood of the "old" deposit. The "new" deposit is underlain by slates, which at the immediate footwall are much weathered and argillaceous, with a coloration ranging from pale pink to white. The junction between the barren clay and the ore-body, although of extreme irregularity, is always clearly discernible. In contradistinction to the "old" deposit, the main mass of the ore is fairly tough and highly manganiferous, while the crumbly ores play a secondary part and occur only at the very uppermost portions near the hanging-wall. The immediate hanging-wall consists of pink clays, 33 to 50 feet thick, very different in character from the footwall clay, but similar in every respect to the clays which occur at the hanging-wall of the "old" deposit: the junction between them and the ore-body, although extremely irregular, the barren portions projecting like tongues into the ore, is well marked. Fragments of ore are occasionally found dispersed in the clays, and frequently quartz-gravel more or less conglomerated. These hanging-wall clays are overlain by sands of various colours and degrees of purity, and these again by drifts.

The conflicting views advanced by those eminent geologists who have investigated these deposits are summarized, and the author then sets forth his own opinion (1) in regard to the "old" deposit, that it arises both from processes of metasomatosis and concentrative sedimentation; (2) in regard to the "new" deposit, that highly carbonated and metalliferous waters reached the surface, and then, partly owing to the action of atmospheric oxygen, and partly owing to the evaporation of carbon-dioxide, the carbonates of iron and manganese were simultaneously oxidized and precipitated. It is noticeable in the "new" deposit that the iron-ores are sharply marked off from those of manganese, owing doubtless to the divergence in capacity of the two metals for oxidation. The waters from which the ores were precipitated evidently came from below. L. L. B.

LOWER CARBONIFEROUS ON THE EASTERN BORDER OF THE UPPER SILESIAN COALFIELD.

Über neuere Aufschlüsse untercarbonischer Schichten am Ostrande des oberschlesischen Steinkohlenbeckens. *By* R. MICHAEL. *Jahrbuch der Königlich Preussischen Geologischen Landesanstalt zu Berlin*, 1907, *vol. xxviii., pages* 183-201, *with* 4 *figures in the text.*

Across the frontier in Austrian Poland recently-made deep borings have proved the productive Coal-measures south of the Vistula at Brescze and

Stare-Stawy, south of Oswiecim, at Polanka Wielka, south-east of the last-mentioned town, and north of the Vistula at Libiaz. At Przeciszow, east of Oswiecim, the Coal-measures were struck at the depth of 1,327 feet from the surface, and continued down to the depth of 1,686 feet, a coal-seam about 2 feet thick being proved at the depth of 1,673 feet. North-east of Przeciszow, in the commune of Olszyny, on the northern bank of the Vistula, a deep boring is said to have proved various coal-seams at depths ranging from 660 to 1,312 feet, a seam exceeding 13 feet in thickness having been struck at the latter depth.

While the Galician Coal-measures as a whole may be correlated with the Upper Silesian synclinal group (none of the borings so far published having recorded the anticlinal seams in Galicia), the productive Coal-measures of Tenczynek must be assigned to the basement series of Upper Silesia, and in the neighbourhood of Krzeszowice a little farther east, the Carboniferous Limestone already makes its appearance. Nay, more, it is probable that the Tenczynek beds are even older than the Upper Silesian basement-measures from which they differ in lithological character; plant-remains are extraordinarily scarce, but animal-remains are somewhat more abundant. The reported occurrence of *Posidonia Becheri* does not affect the question, and the author states that compressed *Anthracosiæ* from the Tenczynek Coal-measure shales have been shown to him as specimens of *Posidonia Becheri*. He takes occasion to refute once again Prof. F. Frech's hypothesis of the upward range of *Posidonia Becheri* into the productive Coal-measures of Upper Silesia, pointing out that the small forms which are all the evidence that Prof. Frech produces cannot with any reasonable certainty be assigned to *Posidonia Becheri* at all. The Tenczynek measures yield, besides coal comparable with the Silesian black coal, a tough, feebly lustrous, dark-brown cannel-coal which has a conchoidal fracture, contains a high percentage of gas, and is very easily inflammable. Of the two exploration-levels driven at Tenczynek, the older and westernmost has proved nine coal-seams, ranging in thickness from 15 inches to over 4 feet. In the great Christina level 590 feet of Jurassic strata were passed through before reaching the Coal-measures, and, after passing through barren sandstones and shales with an anticline of Carboniferous Lime-

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ARSENICAL ORE-DEPOSITS OF REICHENSTEIN, SILESIA.

Über die Arsenerzlagerstätten von Reichenstein. By O. WIENECKE. *Zeitschrift für praktische Geologie*, **1907**, *vol. xv., pages* 273-285.

The mineral-industry in this district, hard by the Austrian frontier, dates, according to documentary evidence, at least as far back as the year 1270, and appears to have reached its culminating point somewhere about the middle of the sixteenth century, more especially under the hegemony of the Fuggers. About the beginning of the eighteenth century, gold-mining, which here had fallen from its former high estate, gave way to arsenical ore-mining; but in 1895, improvements in the chlorination-process allowed once more of profitable extraction of the gold, and since that year the ores have been actively mined both for that metal and for arsenic.

Perhaps the most conspicuous rock of the district is the mica-schist, forming the north-eastern margin of a belt about 1¼ miles in breadth, and consisting mainly of quartz and dark-brown mica. When felspar is added to these constituents, the mica-schist passes into a variety of gneiss. It alone in the neighbourhood of Reichenstein appears to include the bands of dolomitic limestone and the arsenical ore-bodies which are intimately associated therewith. The limestones, of extremely variable thickness and composition, coincide generally in dip and in strike with the enclosing mica-schists. In places, the mica-schists are traversed by granitic dykes, frequently rich in tourmaline, and contain in the vicinity of these dykes red garnets and graphitic inclusions. Although the arsenical deposits extend to the foot of the Jauersberg within the contact-aureole of the granite, direct relationship between them and the granite cannot be postulated.

Westward of the mica-schists, hornblendites and syenites alternate with gneisses; despite their extreme variability from the petrographic point of view, they are manifestly derived all from the same source and are most probably of eruptive origin. No arsenical ores have been found among these rocks so far.

The deposit worked by the only mine at present in activity, the Reicher Trost (or "Rich Consolation") mine, is unsurpassed in productiveness and in magnitude by any of the known ore-deposits of the district. Oft-repeated attempts to re-open the ancient workings on other of these ore-bodies have so far met with failure, and yet along the Landeck high road a line of old heapsteads is observed on each side, for a distance of three-quarters of a mile above the Reicher Trost mine. The ore-body worked here follows on the whole conformably the bedding of the mica-schists, which strike from west-north-west to east-south-east. It would appear to pitch south-westwards at an angle of 30 to 40 degrees; between the first and the fourth deep level the extent of the deposit is about 460 feet; and from the fourth level there is a gradual pinching-out of the eastern portion of the deposit, until at the ninth level the ore-body can only be followed along the strike for a distance of 140 feet or so. It is possible that, in the roof of the ninth level, a fault throws a portion of the deposit down. The thickness of the deposit is extremely variable; about its middle portion, between the fifth and the seventh levels, it reaches a maximum of 100 feet. The deposit, as now seen, has been much changed from its original condition by tectonic phenomena.

At the contact with the ore-lenticle the mica-schist passes into a greyish-green, slightly arseniferous, extremely tough rock in which quartz predominates. The dolomitic limestone immediately associated with the ore-body is of granular texture and a pale-blue colour, occasionally exhibiting dark parallel stripes. It increases in thickness concurrently with the depth, and

at the sixth level measures about 65 feet. Other rocks associated with the deposit are described, such as the *Kammgebirge*, a greyish-green, finely fibrous or compact rock intimately "intergrown" with a pure diopside-rock; and the serpentine, predominant in depth, but also proved at higher levels: now, these are the real carriers of the arsenical ores, which, however, vary in character according to the rock that carries them. In the *Kammgebirge* the arsenical ores occur in finely acicular crystals, intimately intergrown with the associated contact-minerals, seldom forming vein-like stringers. In the serpentine they occur in amorphous masses, associated with more or less finely divided magnetite. The best qualities of these ferro-sulphidic ores, appropriate for immediate smelting, contain about 50 per cent. of pure arsenical ore: they form nests, which along their periphery pass into poorer ores. No general rules can be laid down as to the distribution of the rich ore, either according to strike or according to dip. For the *Kammgebirge* ores the chemical formula suggested is either $Fe_2 As_3$ (leucopyrite) or $Fe_5 As_8$; for the serpentine-ores, the formula found by Dr. C. Güttler is $Fe As_2$ (löllingite). In contrast with these the true arsenical pyrites, associated with the deposits, is of secondary importance and of no industrial consequence. Analytical investigation shows the leucopyrites of the Reicher Trost mine to contain 28·6 parts per million of gold, the löllingites 23·7 parts per million, and arsenical pyrites (from the fourth level) 34·8 parts per million; but the last-named from the Fürstenstollen (Prince's Adit) only contained 5·2 parts per million. Certain details of the chlorination-process of extraction here are kept secret. Since 1895, on an average about 90 pounds of gold (995 fine) have been extracted from the smelter-residues of the arsenical ores.

A description of the other, apparently now unworked, arsenical ore deposits of the district is followed by a detailed consideration of the various hypotheses advanced as to the genesis of the ores. Premising that they have not been found outside the contact-aureole of the Jauersberg granite, the author defines these ore-deposits as typical contact-deposits. It may be noted that the characteristic greenish-grey diopside-rocks, the frequent associates of contact-metamorphosed limestones, are a striking testimony to the probability of this hypothesis. Certain mineral-occurrences are also cited as

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AURIFEROUS DEPOSITS OF BRUSSON, PIEDMONT.

Osservazioni mineralogiche sui Giacimenti auriferi di Brusson (Valle di Aosta). By LUIGI COLOMBA. *Atti della Reale Accademia delle Scienze di Torino,* 1907, *vol. xlii., pages* 904-922, *and* 1 *plate.*

Within recent years exploration-work has been directed to certain lodes of gold-bearing quartz at the localities of Arbaz and Fenillaz, in the valley of the Evançon in the vicinity of Brusson. Although operations have now been abandoned at Arbaz, they are being actively continued at Fenillaz. The author visited the locality in the summer of 1906, with the view of studying the origin of the auriferous deposits, and he now presents the first-fruits of his researches in the form of a mineralogical investigation of the gold and the quartz.

The gold is disseminated in the quartz which forms the infilling of the lodes; and, as may be commonly noted in primary auriferous deposits, it is more abundant high up than low down. In the lower portions of the lodes it is intimately associated with pyrite, and also (though very rarely) with galena and tetrahedrite; in the upper portions of the lodes the gold is in the free state, despite the presence of the other minerals already mentioned, and especially of the pyrite. Where the gold is associated with pyrite it occurs in the midst of that mineral in small dendrites and blobs, which are easily set free as the pyrite decomposes.

The form which the free gold in the upper portions of the lodes assumes depends apparently on the particular habit of the quartz. Thus, where the quartz is compact, the gold is disseminated within its mass in small spangles and "nests." Where, as is the case near the outcrop, the quartz tends to assume a macrocrystalline structure, at some points forming an inextricable tangle of crystals, the gold seems to coat them with a thin film and to interpose itself among them like a cementing-material. In a few cases, calcspar takes the place of quartz in the lodes, and the gold cuts across it in various directions in plates which have a distinctly crystalline structure. At the points of enrichment where there are small cavities in the quartz, the gold generally occurs therein in dendrites, or in crystalline filaments from the extremities of which depend well-defined, lustrous, miniature crystals.

A detailed crystallographic description is given of the dendrites and crystals of the precious metal, noting by the way that some of the latter are curiously distorted. The remainder of the paper consists of a highly elaborate investigation of the quartz-crystals. L. L. B.

GEOLOGY OF THE GROZNY OIL-FIELD, RUSSIA.

Das Naphtagebiet von Groznyj. By K. KALITZKY. *Mémoires du Comité géologique de Russie, new series,* 1906, *No.* 24, *pages* 1-40, *and* 6 *plates.*

West-north-westwards from the town of Grozny in the Terek basin extends for some 14 or 15 miles a range of hills, the maximum elevation of which does not exceed 660 feet. This range is regarded by many Russian authors as a spur of the Sunzha massif; but Dr. Kalitzky points out that it is orographically isolated, being formed by an independent anticlinal fold. The crest of the anticline does not, however, coincide with the summit-line of the range, but is shifted towards the northern flank. Moreover, the crest of the anticline is contorted in the direction of the strike, with the result that the oldest beds crop out in the central portion of the range, but dip away thence qua-quaversally—the dip being steep to the northward and southward, gradual to the eastward and westward. The oil-belt is associated with the domal

region of the anticline, extending somewhat over into the southern limb. Prospectors now carefully avoid the northern limb with its steeply-dipping beds (40 to 90 degrees), even where the dip shows signs of diminution, as all the borings put down on the northern limb have yielded unfavourable results. Thanks to the boring operations which have been going on since 1893, the details of about 500 sections are available—unhappily, their topographical distribution is extremely irregular. Natural exposures, with a few isolated exceptions, are conspicuous by their absence; a mantle of drift-deposits covers the entire range to a depth of 5 or 6 feet, and bears in summer a luxuriant crop of tall grasses and other plants admirably sufficient to conceal old surface-excavations. Nevertheless, investigations conducted in the course of the year 1904 enable the author to give a detailed synopsis of the rock-succession. The entire series falls within the Miocene, and is, in descending order, as follows:—

		Feet.
Mæotic stage.—Akchagil Beds.	Limestones, limestone-conglomerates, calcareous sandstones and clayey sands, calcareous clays.	1,395
Break.		
Middle Sarmatic stage.	Grey shales, with occasional thin flaggy limestones ...	130 to 1,050
	Calcareous clays, with limestones in the upper portion of the group.	312
Lower Sarmatic stage.	Calcareous clays with intercalations of chalk-like marl ...	56
	Calcareous and shaly clays, with frequently interbanded limestones.	141
Passage-beds.	*Spaniodontella*-beds. Shaly and sandy clays, clayey limestones, calcareous clays and sandstones, pure sandstones (all sandstones water-bearing), and limestones.	164
	Chokrak Beds. Shaly and sandy clays, *petroleum-bearing* sandstones (clayey, calcareous, etc.) limestones (frequently nodular), dolomites.	1,214
Mediterranean stage.—*Spirialis*-beds.	Black shaly clays, limestones, black nodular limestones, dolomites.	?

The petroleum-bearing sandstones of the Chokrak group do not crop out at the surface in the area here surveyed; but the scientific value of the bore-

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fault, for instance, the petroleum was so charged with gas as to well forth in a natural fountain; east thereof, the oil from the very beginning had to be pumped up. L. L. B.

PITKÄRANTA ORE-DEPOSITS, FINLAND.

Die Erzlagerstätten von Pitkäranta am Ladoga-See. By OTTO TRÜSTEDT. *Bulletin de la Commission géologique de Finlande,* 1907, *vol. iv., No.* 19, *pages* 1-333, *with* 80 *figures in the text,* 1 *map, and* 19 *plates.*

The preface to this monograph is followed by a bibliography of the subject comprising 130 entries and covering the years 1785 to 1907. About 35 pages are taken up with historical matter, recapitulating the first records of prospecting and exploration-work in the area in the early years of the nineteenth century, and retracing the ups and downs of the mineral-industry of Pitkäranta until its abandonment in 1904. Statistical tables of output are given from 1814 until that year. Although the author states that, at the time of writing, the greater part of the workings were under water, and that the sorting and smelting-houses, etc., were crumbling to ruin, he adds a footnote to the effect that in January, 1907, the entire property passed into the possession of a British syndicate, and that there was consequently reasonable hope of a revival of the mining industry of Pitkäranta.

The district here described embraces that part of the north-eastern coast of Lake Ladoga which belongs to Finland, and is bounded on the east by the great ellipsoidal massif of Rapakivi granite; it presents to the lake a very rugged and much indented coast-line, characterized by numerous skerries and islets. The rocks among which the ore-deposits occur are all of Archæan age, and predominantly early Archæan. Infolded among the pre-Ladogan granite-gneisses, and following all the variations in strike and dip thereof, the Ladogan mica-schists form an elongated basin trending north-westwards, surrounded by a series of smaller basins, to the whole of which the author applies the appellation of the "Pitkäranta syncline." Dioritic schists intrude in great dykes and stockworks into the pre-Ladogan granite-gneisses; between these and the Ladogan schists intervenes a belt of hornblende-schists, 330 to 1,000 feet thick, and at the contact of the hornblendic rocks, both with the pre-Ladogan at their base and with the Ladogan at their summit, occur more or less thick bands of crystalline (mostly dolomitic) limestone and lime-silicate-rock (*skarn*) derived from the last-named. There is a less constant horizon of limestone and *skarn*, some little way up in the hornblende-schists; and all three horizons are ore-carriers, at certain localities. The eruptives of post-Ladogan date (quartz-diorites, granites, pegmatites) cover but small areas in comparison on the one hand with the older rocks just enumerated, and on the other with the still later Rapakivi granite. A detailed description is given of all these, and the tectonic disturbances to which the district has been subjected, now expressed by folds and innumerable faults, are discussed.

From the point of view of the ore-deposits the area is roughly divisible into (1) the "old mining-field" of Pitkäranta, the almost exclusive receptacle of the copper and tin-ores of this region, and by far the most extensive mining-field; (2) the "new mining-field" of Pitkäranta; (3) the mining-field of Hopunvaara; and (4) the mining-field of Lupikko. About 60 pages are devoted to a detailed description of the ore-deposits of the lower zone in the "old mining-field," as proved in more than a score of different mines and workings. In order of abundance the following are the ores here obtained:—Magnetite, chalcopyrite, zinc-blende, cassiterite, pyrite, galena, redruthite, erubescite, magnetic pyrites, and molybdenite, the last-named being evidently the oldest

and possibly the only primary sulphide in these deposits. Native silver, copper, and bismuth are of rare occurrence therein, as also specular iron-ore, fahlore, galena, bismuthite, telluric bismuth, etc. The associated minerals are predominantly lime-magnesia silicates and in part ferruginous lime-alumina silicates, while magnesian silicates, such as serpentine, play a very subordinate part.

Only one deposit in the old mining-field, that of the Ristaus mine, occurs at the upper limestone-horizon; it was first discovered in 1897, by means of magnetometric observations. The deposit is an example of metasomatic replacement of limestone by serpentine intermixed with magnetite (the principal ore here), sulphides of copper and zinc, etc., and cassiterite. Scheelite also is abundantly represented at this mine; indeed, it is of very widespread occurrence throughout the "old mining-field," wherever metalliferous ores are found. The amount of ore-bearing rock in sight at the Ristaus mine, averaging 30 per cent. of metallic iron, is estimated at 150,000 metric tons.

The "new mining-field," a group of deposits extending for a mile and a half nearly due north and south along the eastern limb of the Pitkäranta fold, was practically unknown before the year 1894. Its geological structure is very similar to that of the old mining-field, but pegmatitic intrusions and faults appear to be of much less frequent occurrence. Calculating the mean depth of the ore-bodies at 400 feet or thereabouts (and this would appear to be a conservative estimate) there is a mass of some 4,000,000 tons of magnetic iron-ore available here, without reckoning the sulphides of other metals, such as copper and zinc.

It was only in 1895 that the modern development of geological and magnetometric research showed the long-known Hopunvaara field (the north-eastern extremity of the Pitkäranta syncline), by reason of its extraordinary wealth in magnetic iron-ore, to be one of the most important areas in the entire district. The detailed lithological and mineralogical description of the deposits and the discussion of their mode of formation occupy about 60 pages. The average depth of the ore-bodies being again taken as 400 feet, the amount of available ore averaging from 28 to 30 per cent. of metallic iron is estimated at about 5,000,000 metric tons.

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epigenetic character, nor as to its having been derived from thermal waters carrying metalliferous particles in solution. The same statement holds good of the still later ores—the cassiterite, the sulphides of copper, lead, zinc, etc., and reasons are assigned for regarding the pneumatolytic or sublimation-hypothesis of their origin as untenable. A connexion can be traced between the genesis of the ores and the peripheral contact-metamorphism due to the intrusion of the Rapakivi granite. Finally, an alphabetical list is given of all the minerals discovered in the district described.

It is hardly possible in an abstract to do justice to this memoir, which, thanks to the elaboration of painstaking detail in the accumulation of facts, and to the wealth of illustration employed in presenting them, will long remain as the standard work on the subject. L. L. B.

THE MINING DISTRICT OF NEVIANSK, RUSSIA.

Description géologique du District Minier de Neviansk. *By* A. KRASNOPOLSKY. *Mémoires du Comité géologique de Russie,* 1906, *new series, No.* 25, *pages* 1-106, *and* 1 *map.*

Although this district has long been famous in the annals of gold-mining in the Urals, the author is the first to publish a complete monograph on its geological features. The area is characterized by the enormous development therein of massive crystalline rocks, among which may be mentioned the granitic rocks (including true granites, aplites, pegmatites, gneisses, and biotitic and hornblendic gneissose granites) of widespread occurrence in the eastern and central portions; the augitic and hornblendic porphyrites; the quartz-porphyries, occasionally schistose; the gabbros, which occur principally in the northern and western portions; the serpentines, confined to the north-western and south-eastern portions; and finally, the epidotites and garnet-rocks, obviously of secondary origin, which are associated with all the known deposits of magnetic iron-ore along the Brodovaya river. Metamorphic schists have been observed between Neviansk and the Kunara river, and clearly-stratified " porphyritic " tuffs along the banks of the Tagil, Shurala, and other rivers. An outcrop of Carboniferous Limestone is mapped near Korely, while the Devonian limestones form a broad belt near Neviansk. The only other sedimentary rocks in the district are of post-Tertiary age, including vast deposits of peat, gold-bearing alluvia, yellowish-red lœss-like clays, and also the famous " black earth " (*chernozem*). The gold-bearing alluvia occur in a great number of localities; but auriferous lodes are associated with the porphyrites (near Ayatskoye); with the schists (in the neighbourhood of Neviansk); and with the granites (near Konevsky). Brown hæmatite occurs in irregular nests in the clay which infills the cavities at the surface of the Devonian limestone in the vicinity of Neviansk. The magnetic iron-ore deposits along the Brodovaya, already mentioned, occur in nests, lodes, and impregnations; and the ore-bearing epidosites and garnetites are traversed by steeply-dipping poyphyrite-dykes. With the serpentines near Ayatskoye and Anatolskaya are associated chromite-deposits, and some traces of copper-ore in patches and venules have been observed among the magnetites at the sources of the Bielakovka. Topazes and beryls are found in the pegmatite-veins which traverse the gneissose granites near the Alabashka and Murzinka rivers; raspberry-coloured tourmaline is found in the coarse-grained granitic dykes traversing the serpentines in the neighbourhood of Shaitanskoye, Sarapulka, etc.; and amethysts occur in the white quartz-veins which seam the coarse-grained granite near the villages of Kaigorodskoye, Alabashka, etc.

L. L. B.

CUPRIFEROUS DEPOSITS OF BOR, SERVIA.

Zur Paragenesis der Kupfererze von Bor in Serbien. *By* F. CORNU *and* M. LAZAREVIČ. *Zeitschrift für praktische Geologie,* 1908, *vol. xvi., pages* 153-155, *with* 1 *figure in the text.*

This locality is situated about 19 miles north-east of Zajechar, the chief town of the department of Timok, in Eastern Servia. From Zajechar a light railway runs for 50 miles down to Radujevac, a river-port on the Danube, 80 miles distant from Belgrade, the capital of the little kingdom. The copper-ore deposits of Bor are the richest hitherto discovered in Servia, and are associated with an andesitic eruptive mass, over 30 miles in length from north to south, and from 6¼ to 9¼ miles in breadth. The fundamental rocks of the country are crystalline schists, overlain by Cretaceous sedimentaries, and broken into by numerous igneous intrusions of which the above-mentioned andesitic mass is the chief. According to Dr. D. J. Antula, the cupriferous lodes are arranged in five parallel series from north to south, the general strike being concordant with the direction of tectonic movement and with the trend of the great fissures through which the andesitic magma originally forced its way upwards. The andesite is variously hornblendic, biotitic, and pyroxenic. Near the outcrop, the sulphidic ores (occasionally containing from 110 to 310 grains of gold and from 124 to 154 grains of silver per metric ton) give place to malachite and azurite, associated with decomposed andesite. Twenty-six analyses of the sulphidic ore yielded from 8 to 25 per cent. of metallic copper.

The authors controvert some of Dr. Antula's mineralogical determinations, and they describe, apart from iron-pyrites, as the most abundant sulphidic ores in the deposit: (1) covellite ($Cu\ S$) in splendid dark-blue crystalline aggregates, exactly similar to the mineral of Butte in Montana, intergrown with, or forming venules in, the compact greyish-yellow pyrite; (2) enargite sulph-arsenide of copper) in iron-grey aggregates intimately associated with the covellite and pyrites, or encrusting druses within the last-named mineral. Among the oxidized ores they find pisanite (copper-iron vitriol), in greenish-blue to dark-blue fibrous aggregates, which on exposure to dry air are quickly encrusted with a yellowish-brown film of basic sulphate of iron. Native sul-

[redacted]

was first discovered at the beginning of the eighteenth century; but mining operations on the present extensive scale only date from the year 1902. The enormous rapidity with which the mineral-industry has developed there, may be gauged from the statistics tabulated by the author, showing that already by the end of 1906, the total output of ore for the four years amounted to 5,184,230 metric tons. The Kiirunavaara chain of hills, built up almost entirely of iron-ore, range from north to south, reaching in their highest summit, the Statsrådet, an altitude of 2,456 feet above sea-level. The predominant ore is the so-called "black ore," a very minutely crystalline intermixture in variable proportions of magnetite or specular iron-ore and apatite. Quartz, mica, hornblende, talc, and calcspar are accessory minerals, rarely bulking, however, for more than 2 to 4 per cent. in the intermixture. The Kiirunavaara ore is characterized by its very high percentage of iron, and its variable percentage of phosphorus (ranging from 0·003 to 6·626). Eighteen complete analyses are tabulated, and mean results are also given of seventy-four analyses (iron and phosphorus only). According to the percentage of phosphorus, the ore is graded for the market in six qualities; the proportions of titanium and sulphur are too minute to be taken into account. The deposit at the outcrop covers an area of 70¾ acres, but borings and magnetic-compass observations have proved its extension both northwards and southwards. In fine, the total amount of ore available within the concessions of the Kiirunavaara-Luossavaara Company is estimated at 480,000,000 metric tons.

Luossavaara, as is well known, is a continuation of the deposit just described, from which it is separated only by the lake of Luossajärvi, and yields ore which is practically identical in every respect, except that the proportions of iron and phosphorus are less variable. Eleven complete analyses are tabulated.

The *Nokutusvaara* and *Syvajärvi* deposits, barely 2 miles farther to the north-north-east, were discovered in 1888. Besides "black ore," containing over 2¼ per cent. of phosphorus, specular iron-ore with smaller percentages of phosphorus occurs here. The ores are much seamed by veins of quartz and calcspar. On the whole, these two deposits are of small industrial importance.

At *Haukivaara,* near Kiruna railway-station, about a mile south-east of Luossavaara, red hæmatite occurs in elongated lenticles rarely attaining a thickness of 26 feet, among the "porphyry-schists." Under present circumstances this deposit is not worth working. Some 3 miles south of Kiirunavaara, diggings through the drift have revealed at *Rakkurijoki* a deposit of "black ore," resembling closely in appearance the Gellivare mineral, and containing 42·31 per cent. of metallic iron, 0·25 of phosphorus, and 0·21 of titanic oxide. This deposit is believed to be of some importance.

The *Tuollujärvi* deposit, 3 miles to the east of Luossavaara, first discovered in 1898, has been explored by means of eight borings. It consists of a system of small intersecting lodes infilled with magnetite, or with porphyry rich in magnetite and hornblende. Barely a mile to the south of the comparatively unimportant deposit just described, beyond the lake, lies the *Tuolluvaara* deposit, which is not one of the fourteen included in the arrangement entered into between the mining companies and the Swedish Government. It was discovered in 1897 by Dr. Hjalmar Lundbohm, and exhibits "black ore" with a more or less broad marginal zone of magnetite in the midst of syenite-porphyry. Analyses show the percentage of metallic iron to vary from 64·84 to 71·04, and that of phosphorus from 0·002 to 0·030; titanic oxide was determined in only one case, yielding then 0·53 per cent., and similarly there was but one determination of sulphur, to the amount of 0·04 per cent. The

deposit covers an area of 2½ to 3 acres, and the quantity of available ore, down to a depth of 165 feet or so, is estimated at 2,500,000 metric tons.

About 22 miles south-east of Kiruna railway-station is an important group of deposits, as yet unworked on account of the absence of railway-communication. That of *Mertainen* may be regarded as an "ore-breccia": irregular masses of magnetite are dispersed through a syenite-porphyry breccia, the fragments of which are abundantly cemented by magnetite with some hornblende, and the breccia passes gradually into syenite-porphyry with stringers and amygdules of magnetite, and finally into completely barren syenite-porphyry. The results of fifty-two analyses show the percentage of metallic iron to range from 41·28 to 69·94, and that of phosphorus from *nil* to 1·106 (though, on the whole, it barely averages 0·02). The area of workable ore covers 21 acres, but the geological conditions do not at present permit of an estimate of the probable quantity of ore in sight. The deposit of *Painirova*, south of that just described, is of very similar character, but of less importance. The *Svappavaara* deposit, another of those not included in the above-mentioned arrangement, was worked as long ago as the seventeenth century for its copper-ores: after many years of neglect and oblivion, attention was called to its wealth in iron-ore in 1875. "Black ore" and red hæmatite occur in huge lenticles among syenite-granulites: with these ores, which pass gradually one into the other, are associated apatite and calcspar. The percentage of metallic iron in the "black ore" ranges from 43·20 to 65·85, and that of phosphorus from 0·632 to 3·188. In the red hæmatite, the corresponding extreme variations are 48·12 to 70·09 per cent., and 0·033 to 1·260. The deposit covers an area of about 12½ acres; reckoning from the outcrop at the top of the hill down to the level of the projected railway (230 feet) there are 13,000,000 metric tons of ore in sight; but, if we reckon down to the level of the surrounding marshes (100 feet lower), the quantity of ore probably available is increased to 19,000,000 metric tons. Barely a mile and a quarter distant is the equally important deposit of *Leveäniemi* (also outside the pact) proved by means of magnetometric measurements some ten years ago. Out of twenty-three borings, nineteen have struck ore below the drift, going in some cases through a thickness of 180 feet or more of pure iron-ore, [redacted]

61·07; and in the smaller lenticles, 63·15. The respective percentages of phosphorus are 1·27, 1·46, and 1·094. The total area exceeds 12 acres, and the amount of ore in sight down to a depth of 460 feet is estimated at 30,000,000 metric tons. The mass can be worked opencast to a depth of 260 feet or more.

The deposits of *Laukujärvi* (3 miles north of that just described), *Toppi* or *Njuotjamaluspavaara*, and *Nakerivaara* do not come under the contract with the Swedish Government, and are not, apparently, of industrial importance.

Voluminous statistics are given of the output and consumption of iron-ore in the principal countries of the world, and more especially in Germany (including in the case of that country statistics of import and export); also of the output, export, and consumption in Sweden itself from 1897 to 1906; and it is shown that the German Empire is now Sweden's principal foreign customer for iron-ore. The before-mentioned contract with the Swedish Government limiting, as it would seem to do, the exports to fixed quantities during the next twenty years (with the probable intention of promoting the growth of the native metallurgical industries by retaining a certain proportion of ores for their use within the country), may in time cause German iron-founders and steel-manufacturers to look elsewhere for the needful supply of raw material.

L. L. B.

INDEX TO VOL. XXXV.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word ; and in the case of Names, it includes both the Christian Name and the Surname; or, in the case of the name of any Firm, Association or Institution, the full name of such Firm, etc.

Discussions are printed in *italics*.

The following contractions are used :—

M. C.—The Midland Counties Institution of Engineers.

M. G.—Manchester Geological and Mining Society.

M. I.—Midland Institute of Mining, Civil and Mechanical Engineers.

N. E.—The North of England Institute of Mining and Mechanical Engineers.

N. S.—The North Staffordshire Institute of Mining and Mechanical Engineers.

S. I.—The Mining Institute of Scotland.

S. S.—The South Staffordshire and Warwickshire Institute of Mining Engineers.

A.

B.

[redacted]

C.

D.

E.

[redacted]

G.

H.

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T.

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V.

W.

[redacted]

Y.

Z.

[redacted]

The Institution of Mining Engineers
Transactions 1907-1908.
Vol. XXXV, Plate I.

To illustrate Mr J. Wroe's "Notes on a Recent Underground Fire at Wharncliffe Silkstone Collieries, and the use of Rescue-apparatus in Connection therewith."

Fig. 1.—Plan of Motor-house.

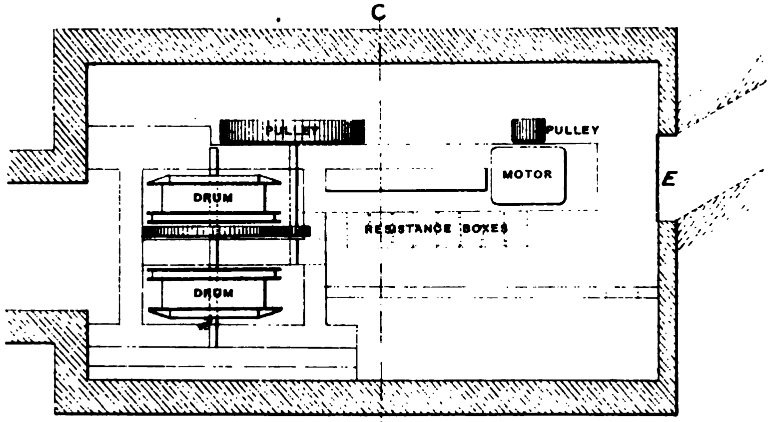
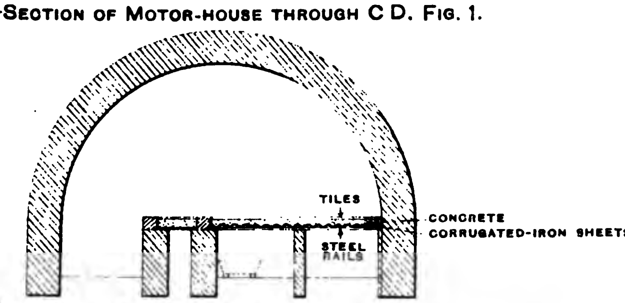
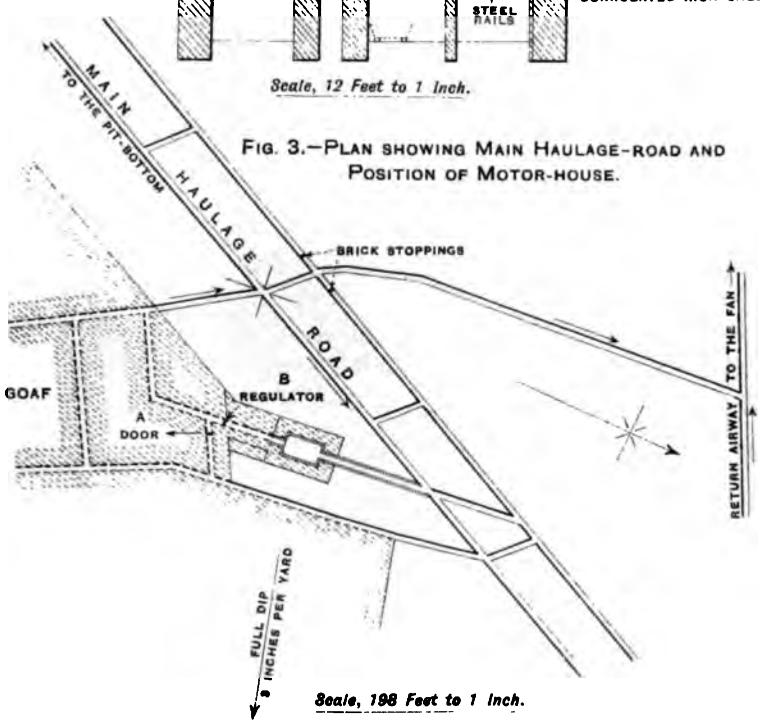


Fig. 2.—Section of Motor-house through C D, Fig. 1.



Scale, 12 Feet to 1 Inch.

Fig. 3.—Plan showing Main Haulage-road and Position of Motor-house.



Scale, 198 Feet to 1 Inch.

Midland Institute of Mining, Civil & Mechanical Engineers.
Transactions 1907-1908.
Vol. XVIII, Plate IX.

Andw Reid & Compy Ltd Newcastle upon Tyne

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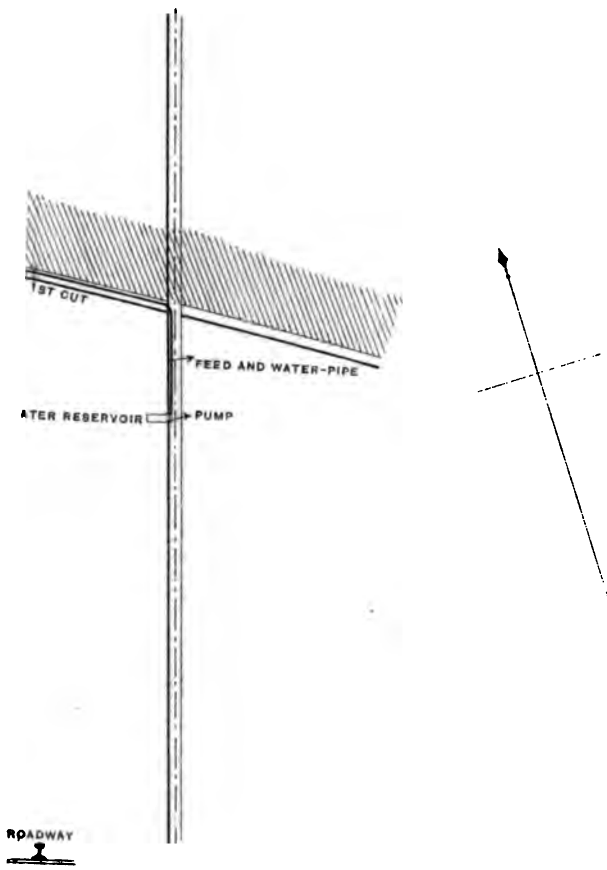
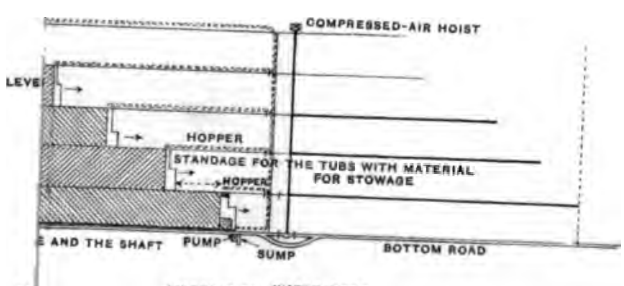
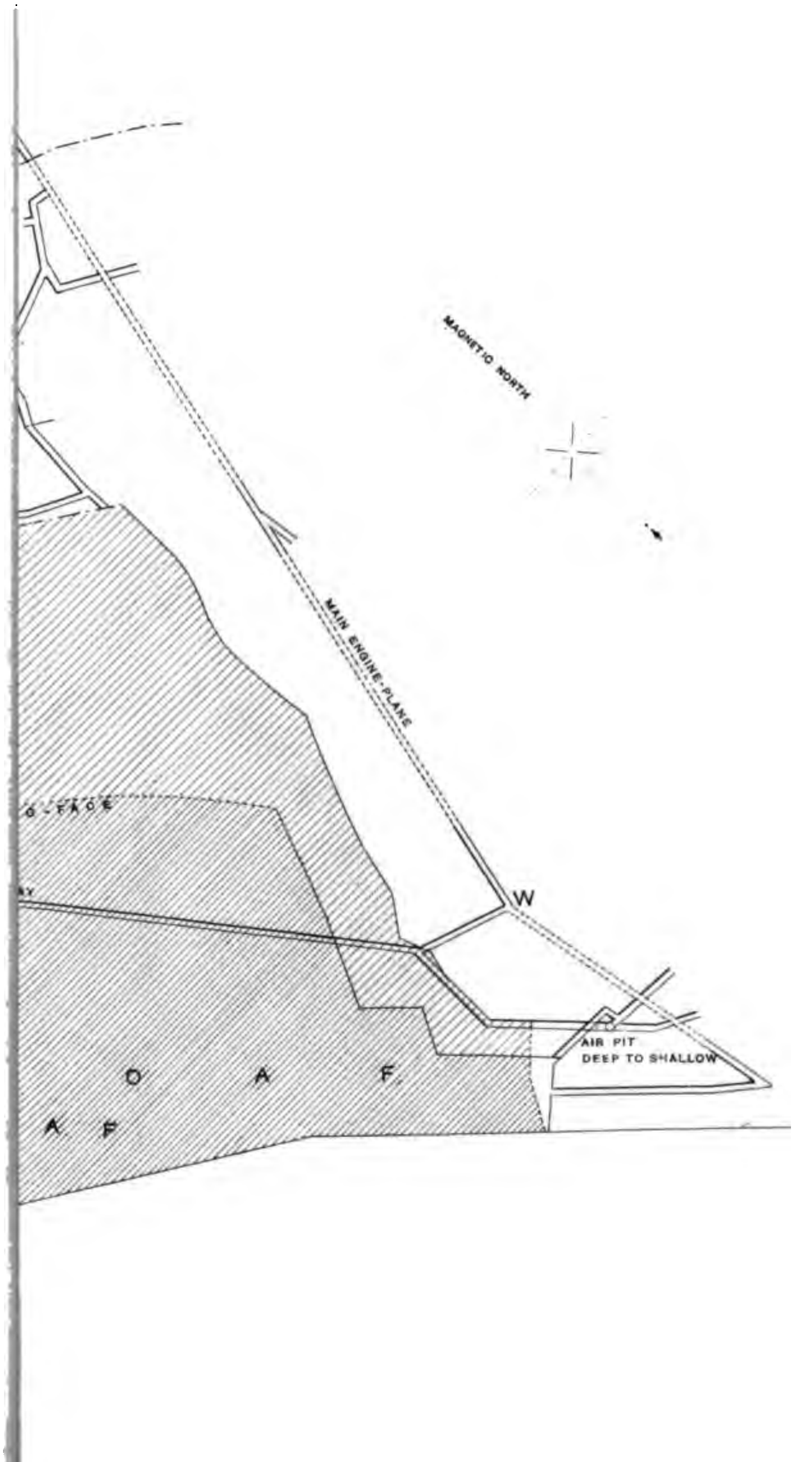


A — OF WORKING BY CUTS AND PACKING OF ROADS; HALF THE FIRST AND QUARTER BEING OPENED OUT: HALF THE FIRST LEFT-HAND R UNDER EXTRACTION.



WATER-PIPES.


MAGNETIC NORTH
MAIN ENGINE-PLANE
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AIR PIT
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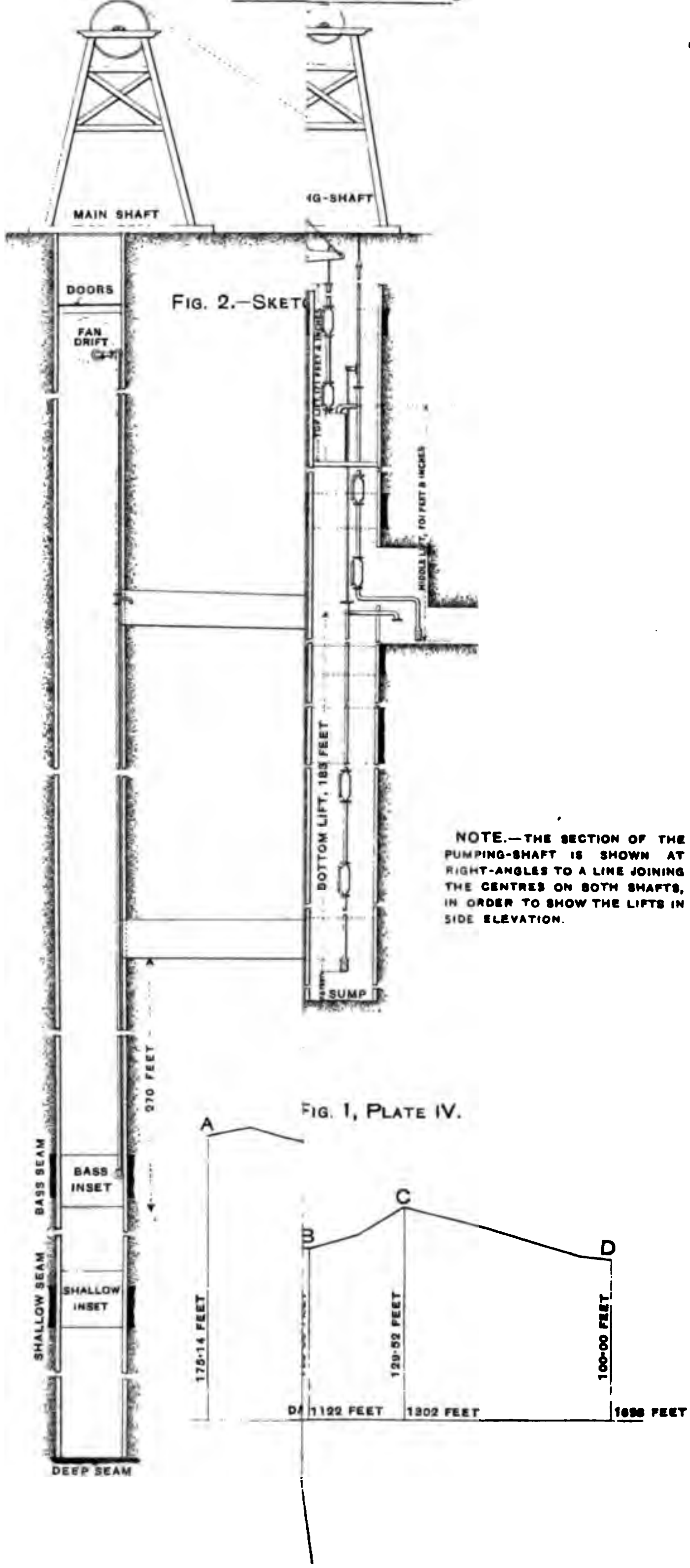

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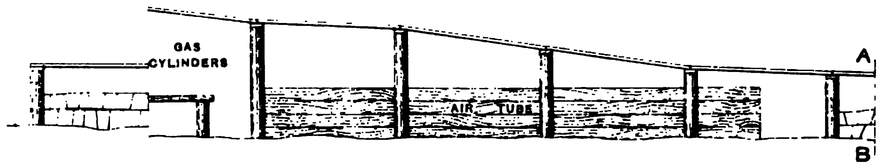
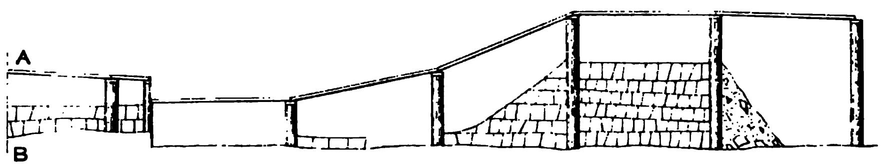
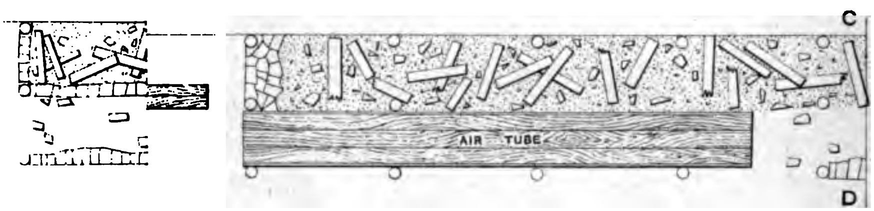
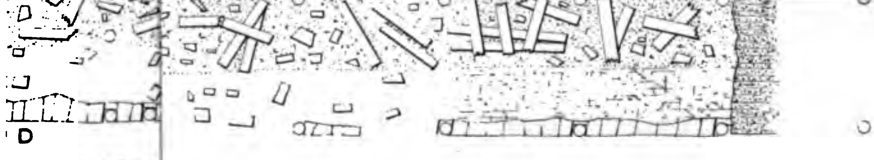






GAS CYLINDER

GAS CYLINDER



escue-apparatus, Felling."

Rescue-apparatus, Felling."

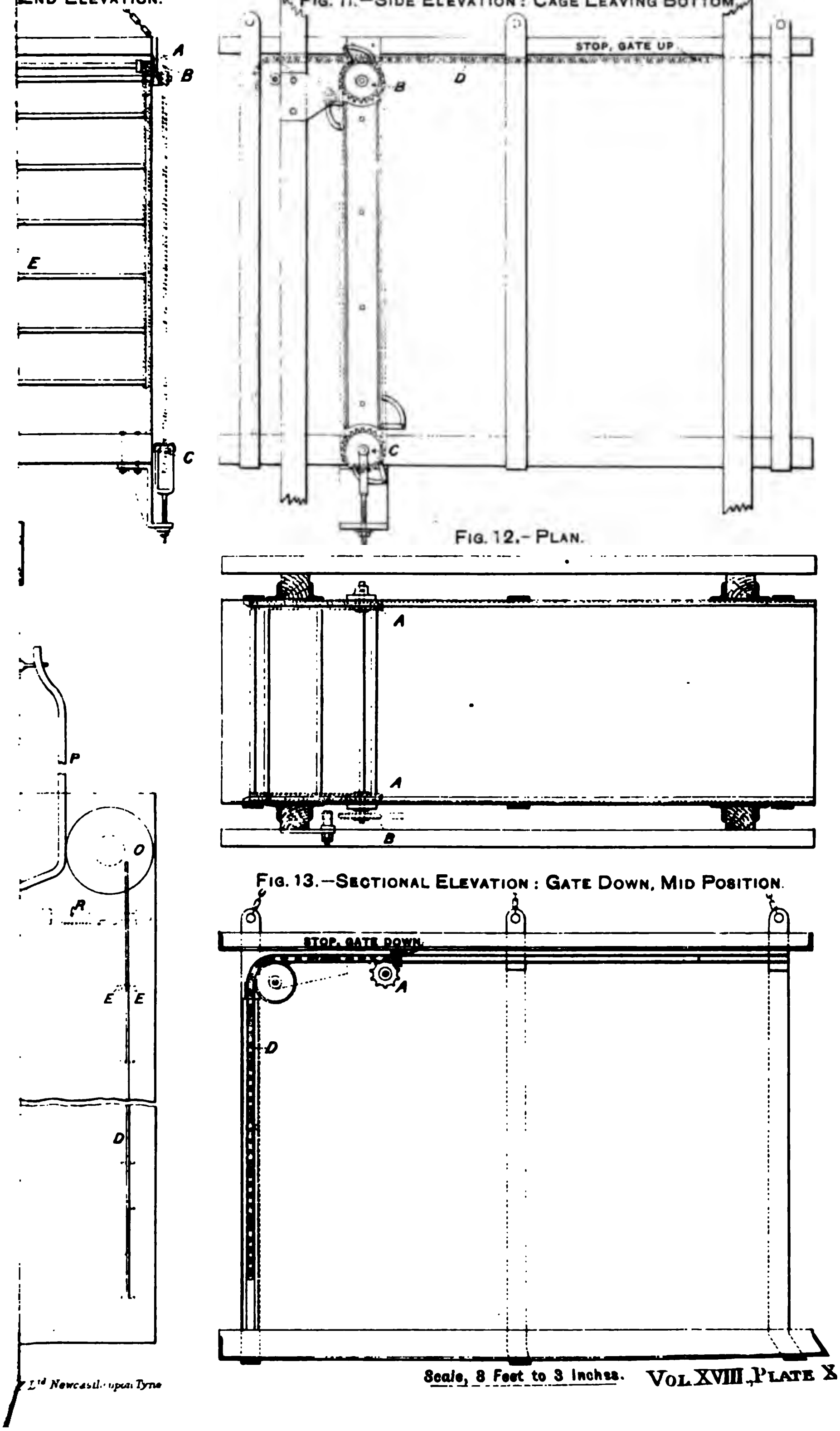
To illustrate Mr. Lawrence Austin's Description of the "Demonstration of Rescue-apparatus, Felling."

END ELEVATION.

FIG. 11.—SIDE ELEVATION: CAGE LEAVING BOTTOM.

FIG. 12.—PLAN.

FIG. 13.—SECTIONAL ELEVATION: GATE DOWN, MID POSITION.



Scale, 8 Feet to 3 Inches.

Ltd Newcastle-upon-Tyne

GE APPROACHING BOTTOM :
FENCE CLOSED.

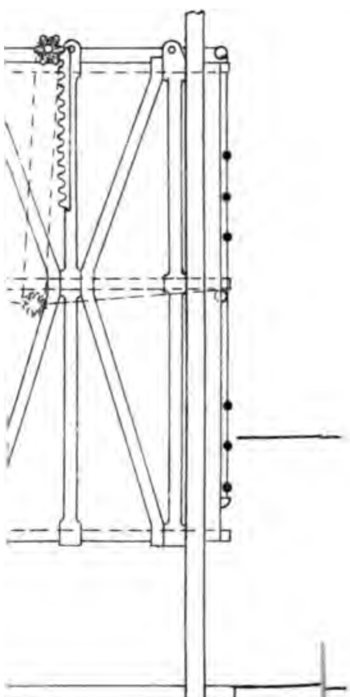
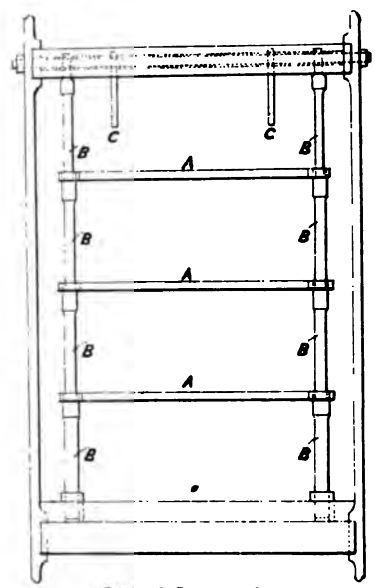


Fig. 23.—Richardson Cage-gate.



Scale, 2 Feet to 1 Inch.

AGES.

Fig. 20.

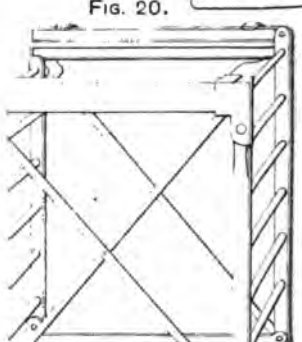


Fig. 21.

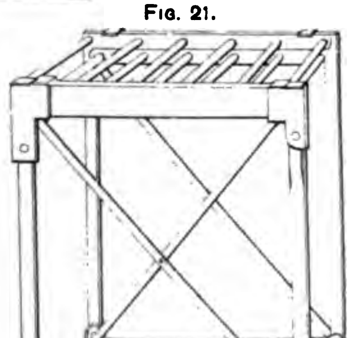
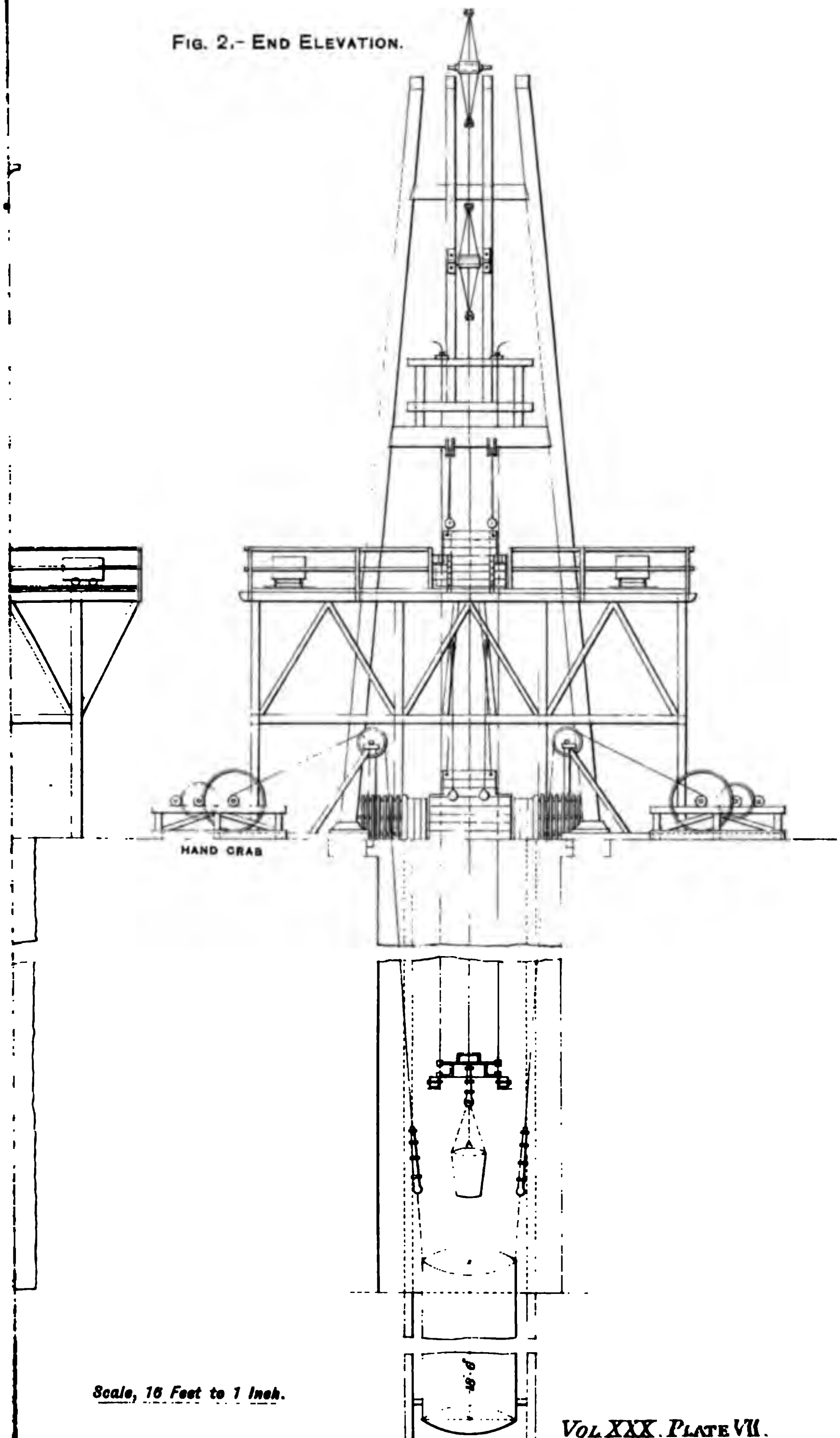


FIG. 2.- END ELEVATION.



Scale, 16 Feet to 1 Inch.

To illustrate Mr. James Ashworth's Reply to the Discussion on his Paper on "Air-percussion and Time in Colliery Explosions."

Fig. 1.—Plan of the Lecœuvre Heading in Josephine Seam (Fig. II, Plate XXV., Volume XXXII.)

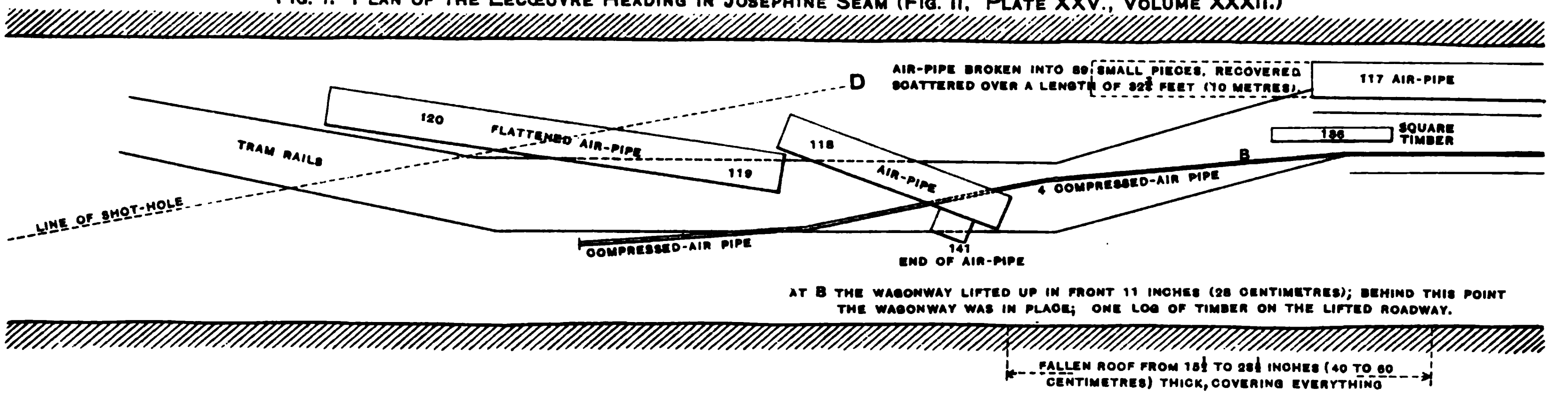
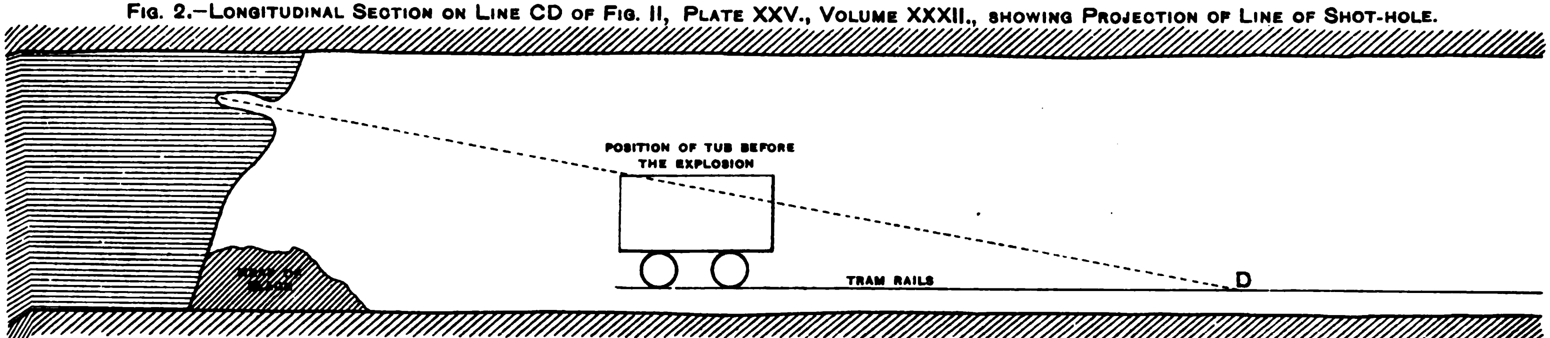


Fig. 2.—Longitudinal Section on Line CD of Fig. II, Plate XXV., Volume XXXII., showing Projection of Line of Shot-hole.



Scale, about 5½ Feet or 66¾ Inches to 1 Inch.

Andw. Reid & Compy. Ltd. Newcastle upon Tyne

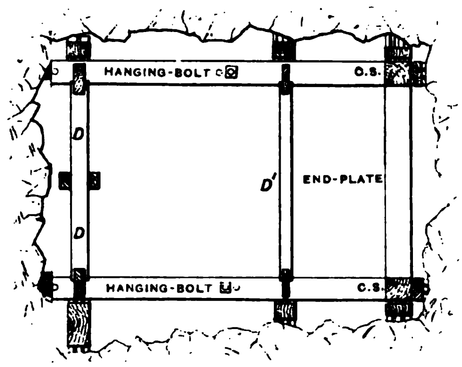
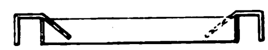
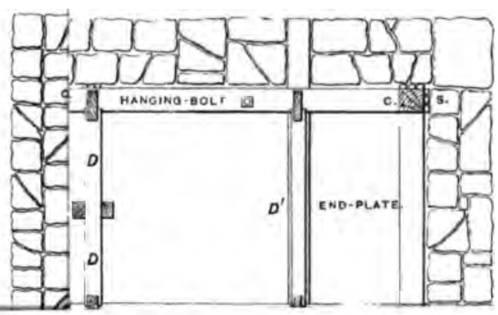


Fig. 5.—Divider, with Detachable Hooks.

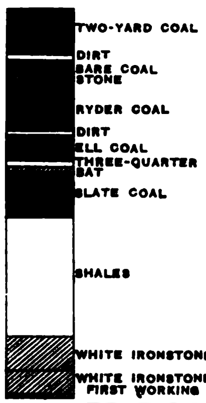




Scale, 6 Feet to 1 Inch.

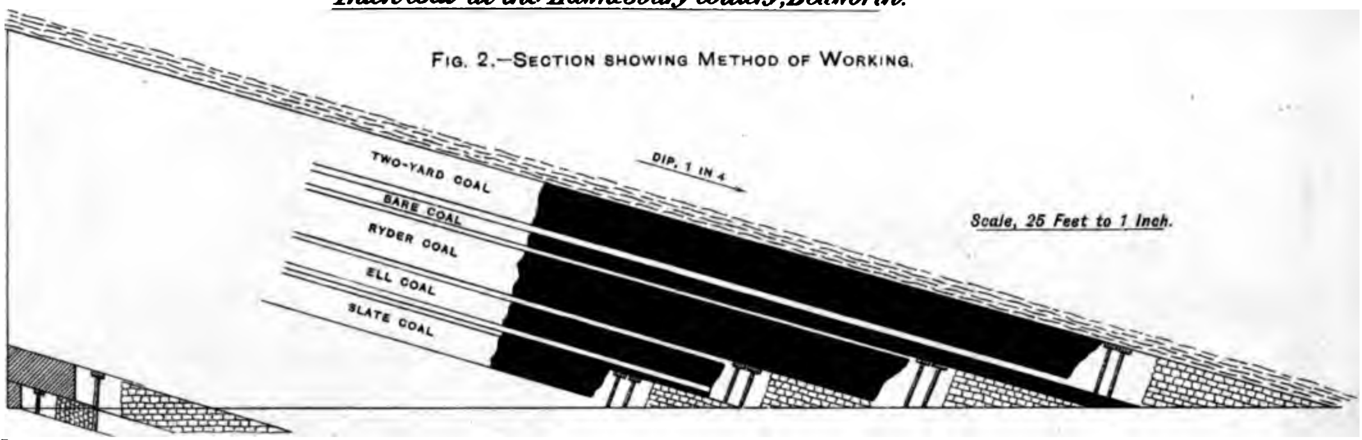
To illustrate Mr. James Cunliffe's Paper on "Methods of Working the Warwickshire Thick Coal at the Hawkesbury Colliery, Bedworth."

Fig. 1.—Section of Strata.



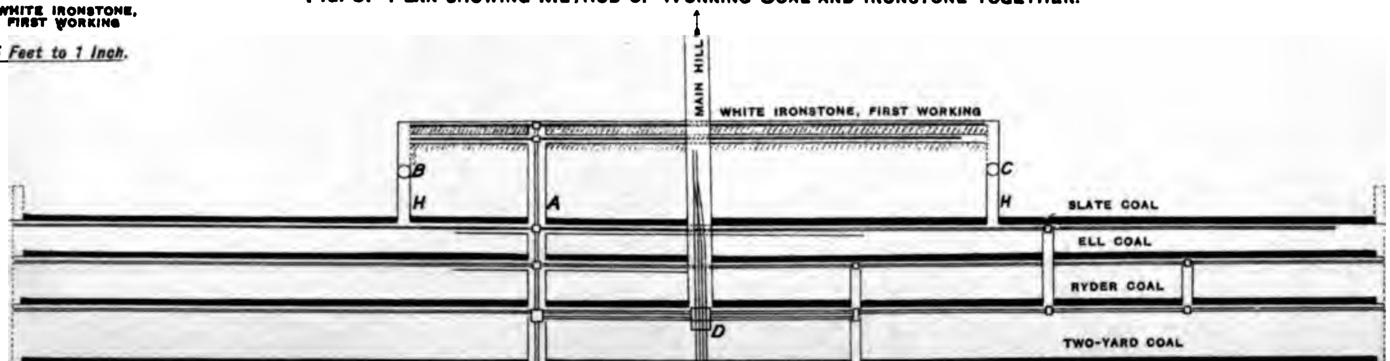
Scale, 25 Feet to 1 Inch.

Fig. 2.—Section showing Method of Working.



Scale, 25 Feet to 1 Inch.

Fig. 3.—Plan showing Method of Working Coal and Ironstone together.



Scale, 100 Feet to 1 Inch.

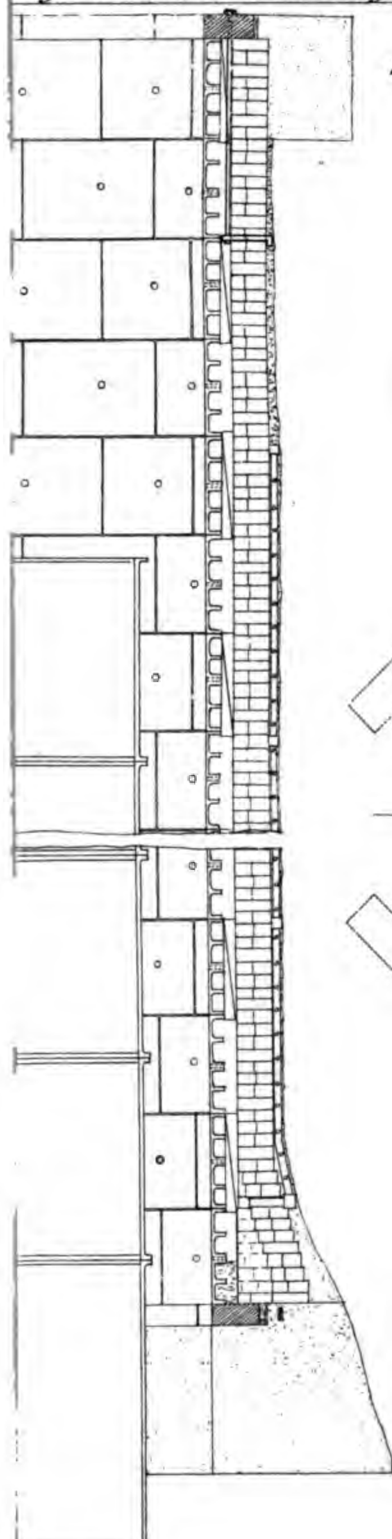
Andw. Reid & Compy. Ltd. Newcastle upon Tyne.

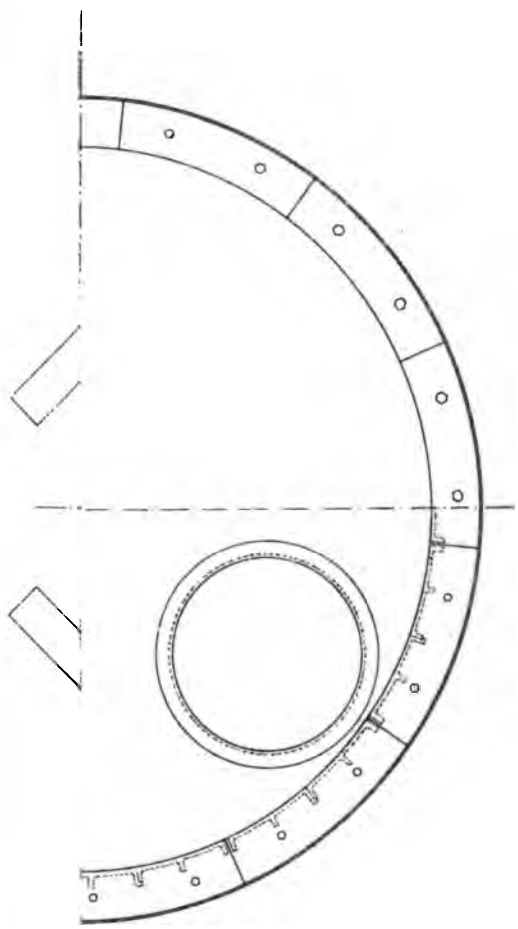
ing a Well, etc., at Altham Bridge,

Vol. XXXV., Plate XVII.

ArBridge Pumping-station.

—Plan.





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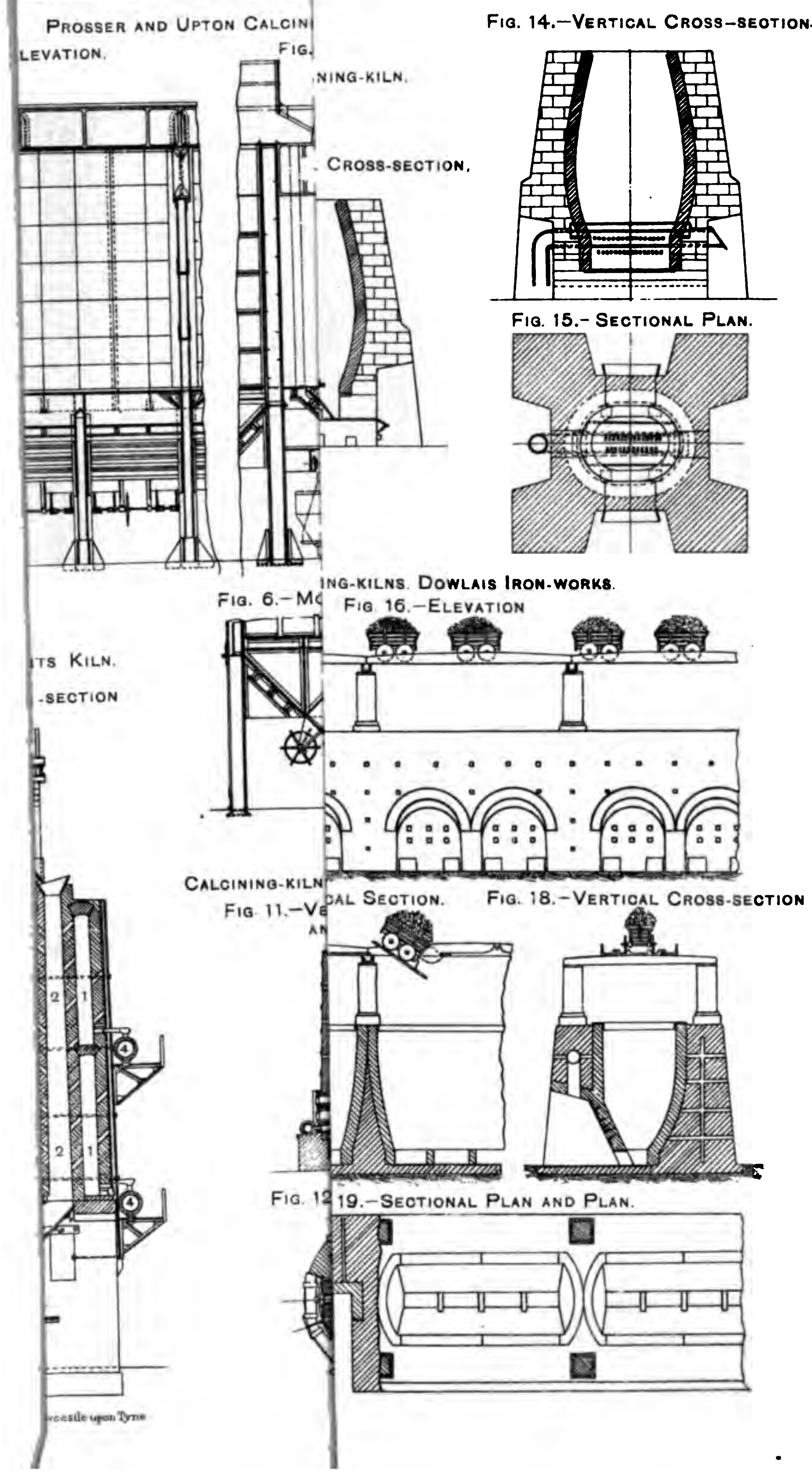
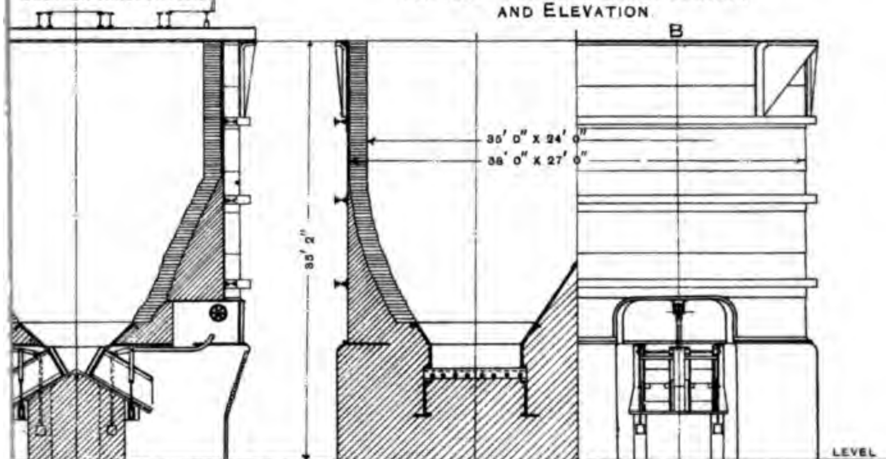
Vol. XXX., Plate IX.


PROSSER AND UPTON CALCINI
LEVATION.
FIG.
NING-KILN.
CROSS-SECTION.
FIG. 14.—VERTICAL CROSS-SECTION.
FIG. 15.- SECTIONAL PLAN.
ING-KILNS. DOWLAIS IRON-WORKS.
FIG. 6.—MC
FIG. 16.—ELEVATION
TS KILN.
-SECTION
CALCINING-KILN
FIG. 11.—VE
AN
CAL SECTION.
FIG. 18.—VERTICAL CROSS-SECTION
2
1
4
FIG. 12
19.—SECTIONAL PLAN AND PLAN.
castle upon Tyne

OVAL-KILN (1894). DRAWN BOTH SIDES. CLARENCE IRON-WORKS.

SECTION THROUGH AB.

FIG. 38.- VERTICAL CROSS-SECTION AND ELEVATION



CIRCULAR-KILN, NEW TYPE. DRAWN TWO SIDES. CLARENCE IRON-WORKS.

FIG. 35.-VERTICAL CROSS-SECTION.

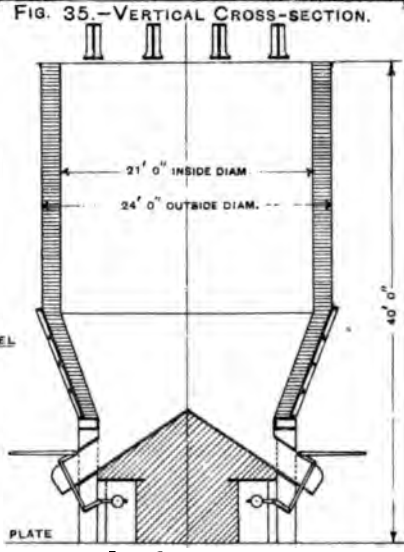
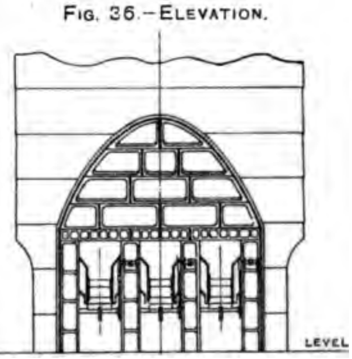


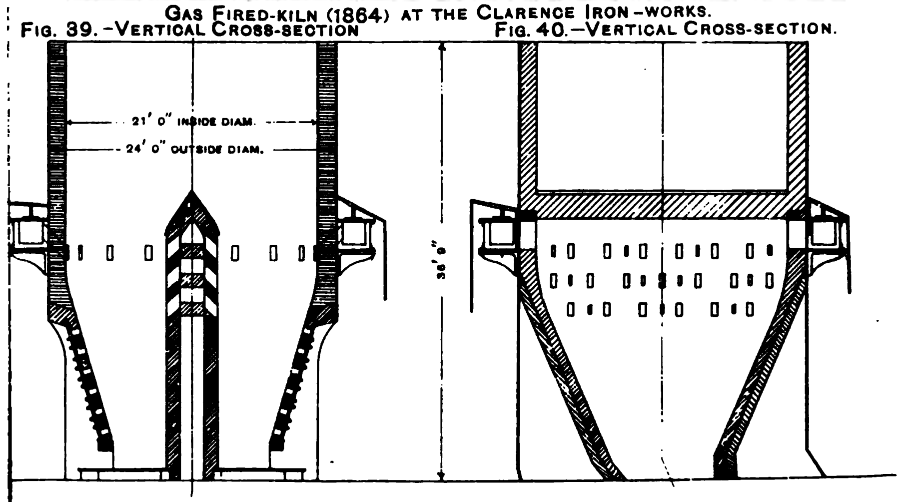
FIG. 36.-ELEVATION.



GAS FIRED-KILN (1864) AT THE CLARENCE IRON-WORKS.

FIG. 39.-VERTICAL CROSS-SECTION

FIG. 40.-VERTICAL CROSS-SECTION.



BONIFEROUS LIMESTONE OF DERBYSHIRE,
›R-BEARING VEINS AND PIPES.

REFERENCES.

BOUNDARY OF CARBONIFEROUS LIMESTONE

FLUOR-BEARING VEINS

FLUOR-BEARING PIPES

OTHER MINERAL-VEINS

OTHER MINERAL-PIPES

ESENTATION OF MINERAL-VEINS, ETC., OTHER THAN THOSE BEARING FLUORSPAR, IS
OM THE 1-INCH MAPS OF THE GEOLOGICAL SURVEY, WITH SLIGHT MODIFICATIONS.

Fig. 8.

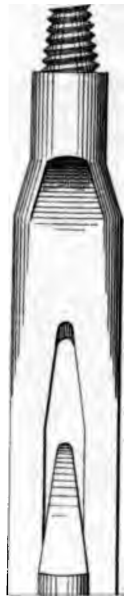
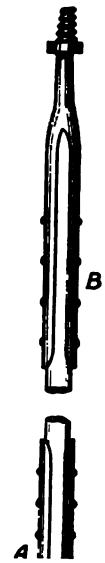


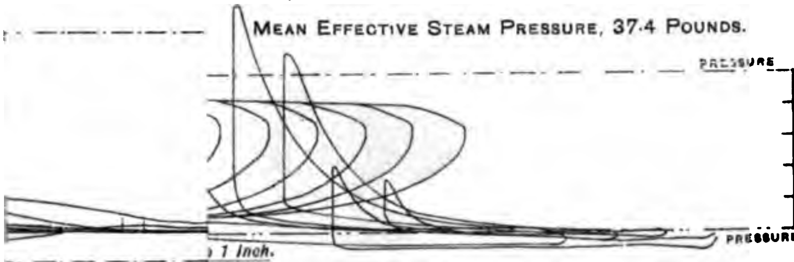
Fig. 9.

Fig. 10.

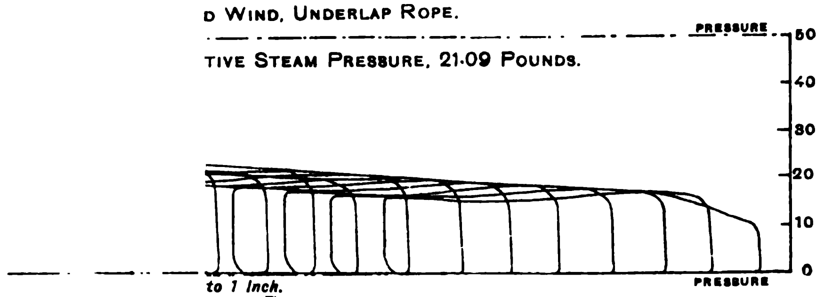


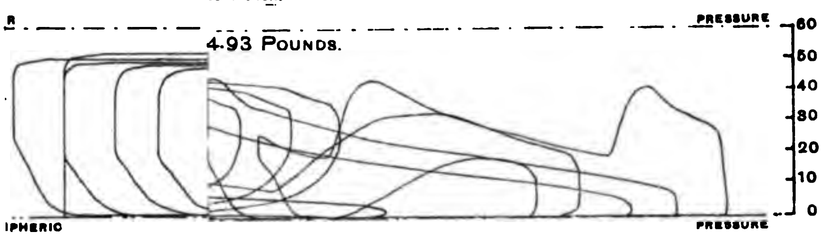
F NOS. 1, 2, 3, ...

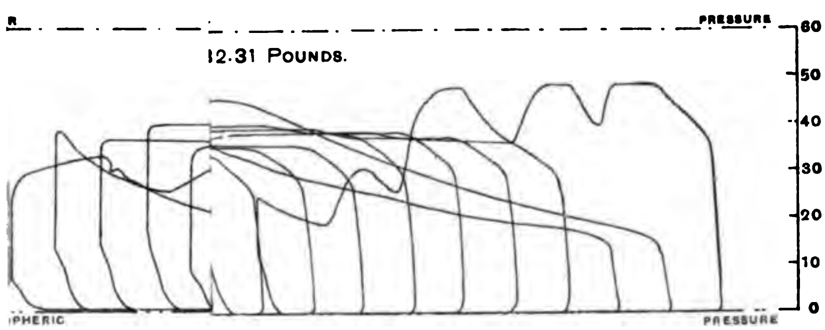
...D WIND, OVERLAP ROPE.

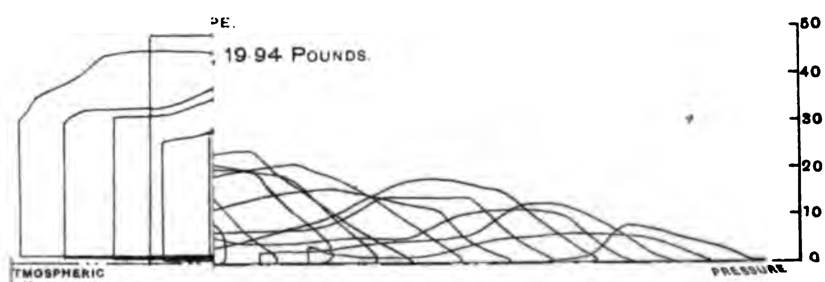


D WIND, UNDERLAP ROPE.









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engine Tests, with

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G ENGINE.

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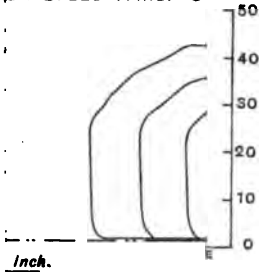
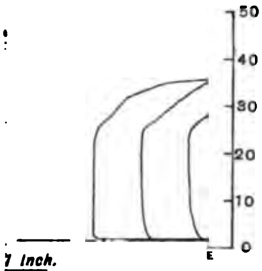
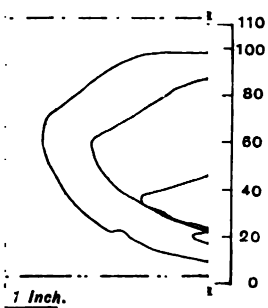
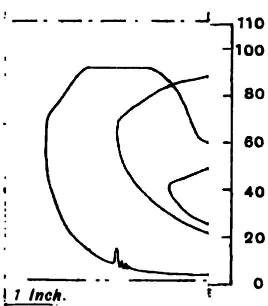
OW SPEED WIND.—U





LL SPEED WIND —OV





1·79 2·48

18

And^w Reid

LOAD DATA.

DEPTH OF WIND	1,024·6 FEET.
DEAD LOAD (UNDERLAP ROPE)	5,273 POUNDS.
DEAD LOAD (OVERLAP ROPE)	4,783 ,,
MEAN LOAD	5·028 ,,
CAGES, CHAINS, &c.	14,560 ,,
TUBS	5,340 ,,
WINDING ROPES	9,850 ,,
TOTAL MASS ..	34,778 ,,

TACHOMETER DATA.

TIME OF WIND (MEAN) ..	34·8 SECONDS.
TIME UNDER STEAM	20·4 ,,
MAXIMUM ROPE SPEED ..	46·7 FEET PER SECOND.
MEAN ROPE SPEED	29·44 ,, ,, ,,
MEAN RATE OF ACCELERATION	2·29 FEET PER SECOND PER SECOND
MAXIMUM PISTON SPEED ..	560 FEET PER MINUTE.

EFFECTIVE WORK IN RAISING LOAD, UNDERLAP SIDE ..	5,402,716 FOOT-POUNDS.
EFFECTIVE WORK IN RAISING LOAD, OVERLAP SIDE ..	4,900,662 ,, ,,

SLOW SPEED WIND.

UNDERLAP ROPE.

MEAN EFFECTIVE STEAM PRESSURE	20·56 POUNDS.
INDICATED WORK IN CYLINDERS	5,875,431 FOOT-POUNDS.
MECHANICAL EFFICIENCY	91·96 PER CENT.

OVERLAP ROPE.

MEAN EFFECTIVE STEAM PRESSURE	18·56 POUNDS.
INDICATED WORK IN CYLINDERS	5,303,891 FOOT-POUNDS.
MECHANICAL EFFICIENCY	92·39 PER CENT.
MEAN EFFICIENCY	92·17 PER CENT.

FULL SPEED WIND.

OVERLAP ROPE.

MEAN EFFECTIVE STEAM PRESSURE	34·70 POUNDS.
REVOLUTIONS UNDER STEAM (MEAN)	14·5
INDICATED WORK IN CYLINDERS ..	7,013,911 FOOT-POUNDS.
KINETIC EFFICIENCY AT FULL SPEED	69·87 PER CENT.
MEAN INDICATED HORSEPOWER ..	625.
MAXIMUM INDICATED HORSEPOWER	992.

NOTE.—THE NET WEIGHT OF COAL FOR EACH TEST WAS 5,028 POUNDS, BUT THE CAGE AND TACKLE ON THE UNDERLAP SIDE WAS FOUND TO BE 245 POUNDS HEAVIER THAN THAT ON THE OVERLAP SIDE.

...TA.

677·4 FEET
3,472 POUNDS

...ONSUMPTION

NOVEMBER

2,351,933 FOOT POUNDS

...CK END.
...M PRESSURE

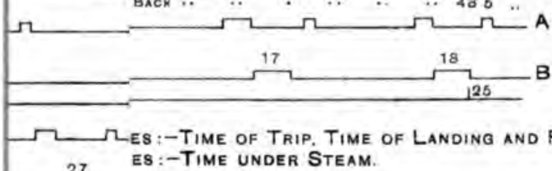
89·1
...URE 34·76 POUNDS
3,195,844 FOOT POUNDS
...R 322·8
121·0
87·75 PER CENT.
73·6 ..
2,804,353 FOOT POUNDS
...WER
106·2

STEAM CONSUMPTION.

TOTAL STEAM USED	10,725 POUNDS.
STEAM PER INDICATED HORSEPOWER HOUR	86·6 .
STEAM PER MECHANICAL HORSEPOWER HOUR	100·9 ..
STEAM PER EFFECTIVE HORSEPOWER HOUR	120·3 ..

TACHOMETER DATA.

	MEAN.	TOTAL.
...EST		1 HOUR 48 MINUTES
...DS		75
...NG	26 SECONDS	32 MINUTES 30 SECONDS
...TEAM	18 ..	22 .. 30 ..
...AND REVERSING	12·7 ..	15 .. 41 ..
BACK	43 5 ..	59 .. 49 ..



...ES :—TIME OF TRIP, TIME OF LANDING AND RUNNING BACK.
...ES :—TIME UNDER STEAM.

...TA.

2,351,933 FOOT POUNDS

NOVEMBER 1...

100·9

...ACK END.
...AM PRESSUR...

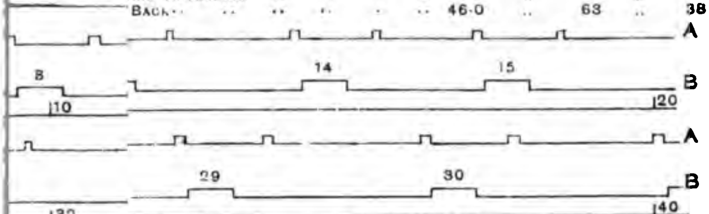
...URE 34·87 POUNDS
2,820,006 FOOT POUNDS
...R 301·6
121·0
87·75 PER CENT.
83·4 ..
2,474,552 FOOT POUNDS
...WER
106·2

STEAM CONSUMPTION.

TOTAL STEAM USED	10,687 POUNDS
STEAM PER INDICATED HORSEPOWER HOUR	87·9
STEAM PER MECHANICAL HORSEPOWER HOUR	100·1
STEAM PER EFFECTIVE HORSEPOWER HOUR	105·4

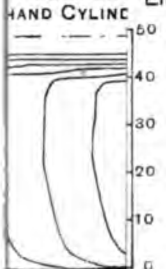
TACHOMETER DATA.

	MEAN.	TOTAL.
...EST		1 HOUR 53 MINUTES
...DS		85
...NG	28·1 SECONDS.	39 MINUTES 48 SECONDS
...EAM	17·0 ..	24 .. 05 ..
AND REVERSING	6·9 ..	9 .. 34 ..
BACK	46·0 ..	63 .. 38



LINE A GIVES :—TIME OF TRIP, TIME OF LANDING AND RUNNING BACK.
LINE B GIVES :—TIME UNDER STEAM.

12·5 AND 11
...HAND CYLINC...



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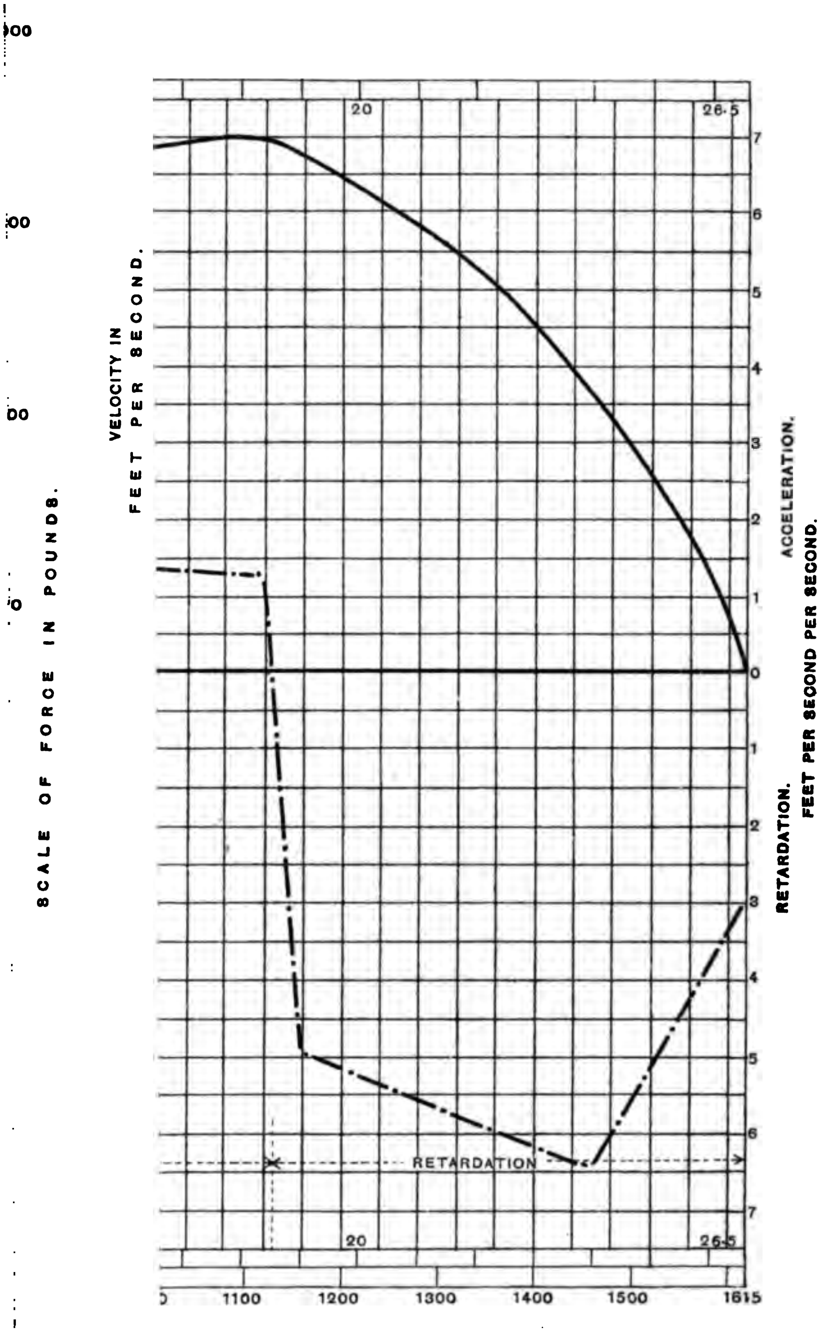
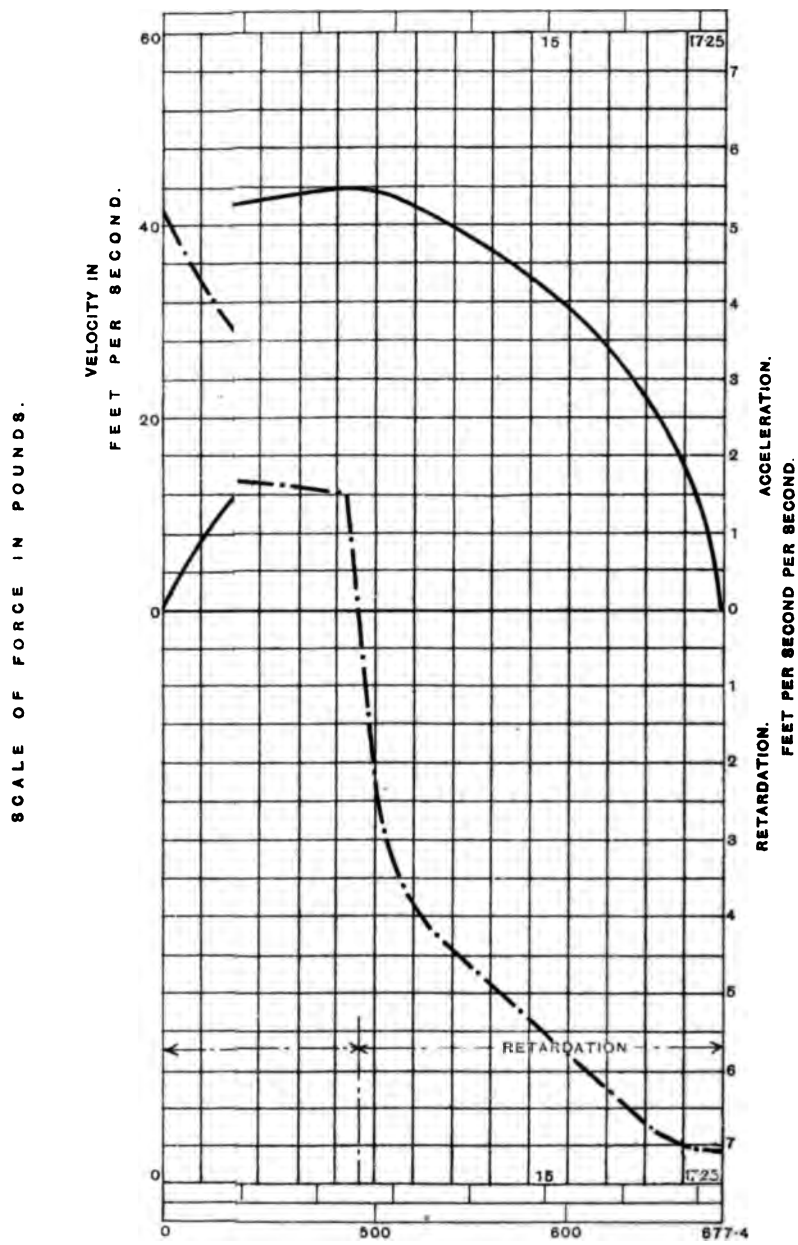
RAM.



Comp.y L.td Newcastle up

VINDING-PLAN

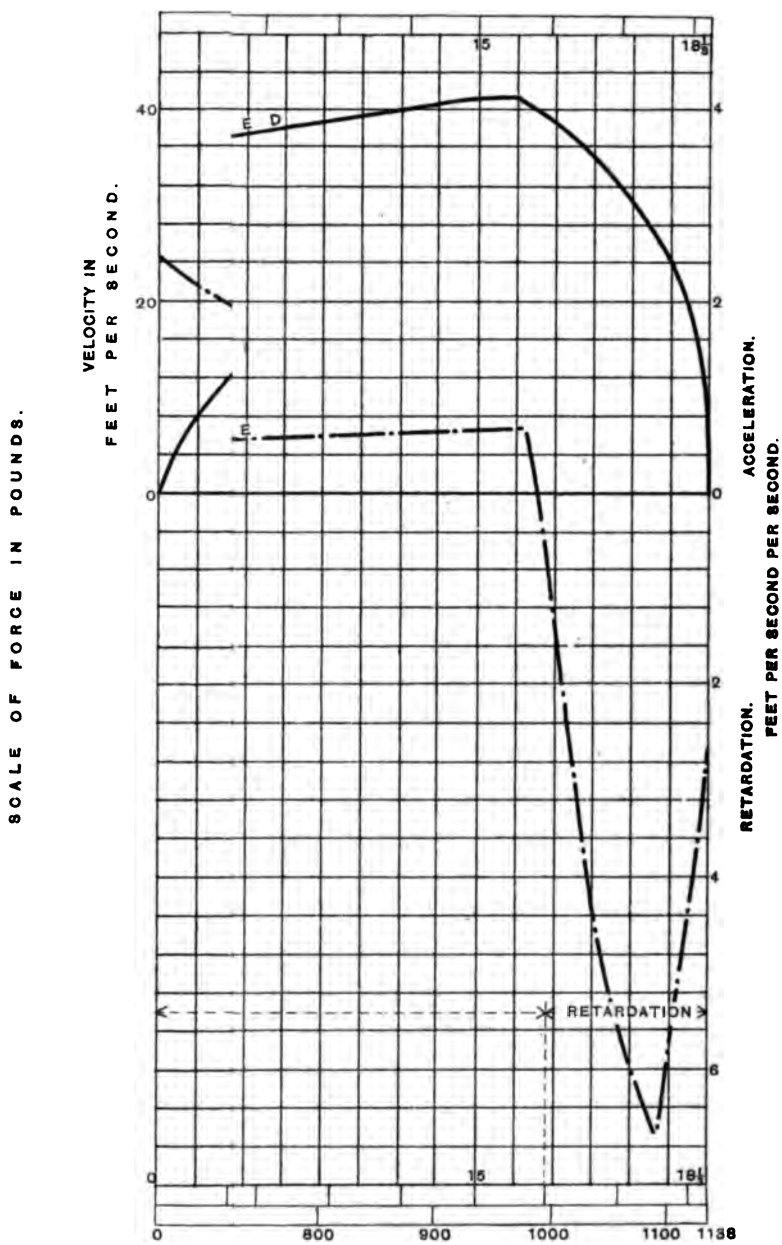
AGRAM.



Comp.y L.td Newcastle upon Tyne

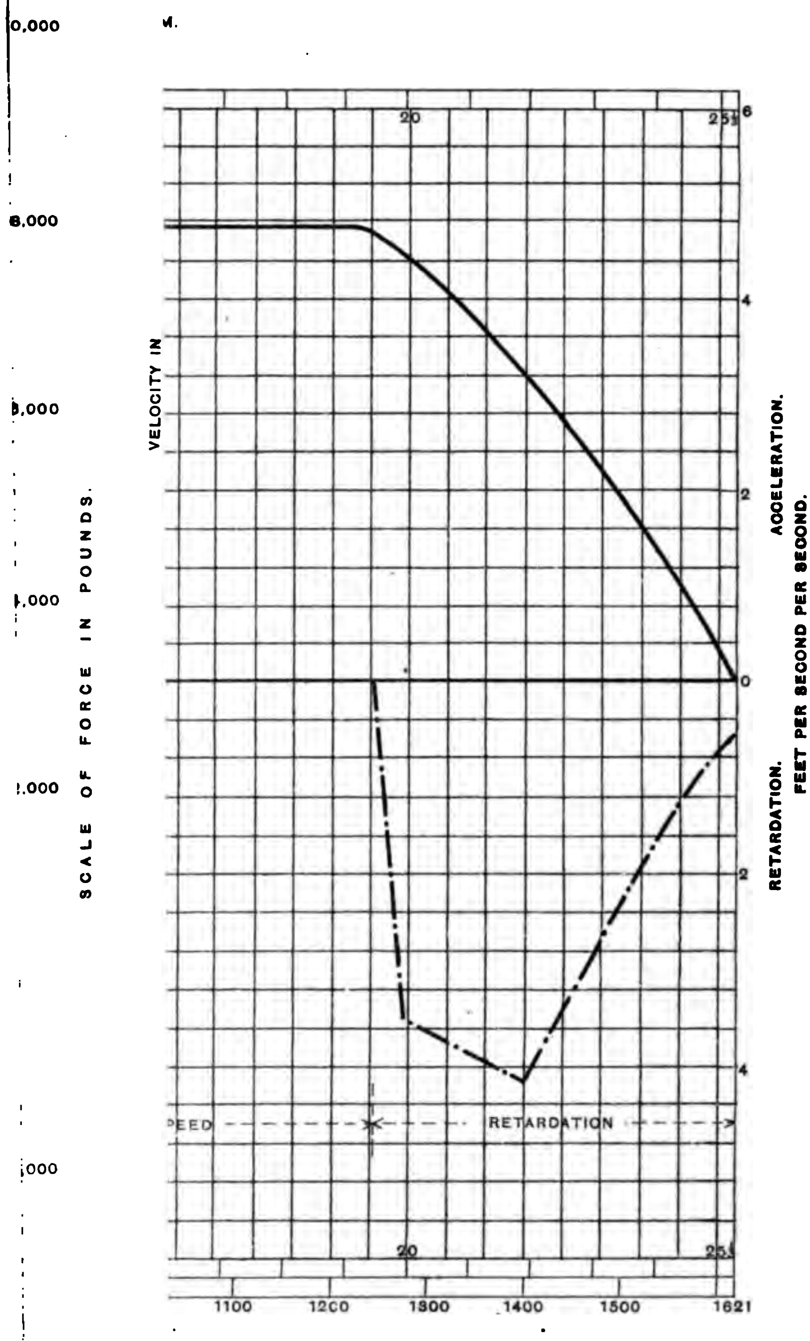
INDING-PLANT

IRAM



mpy. Ltd. Newcastle upon Tyne.

WINDIN



Reid & Co. Ltd New

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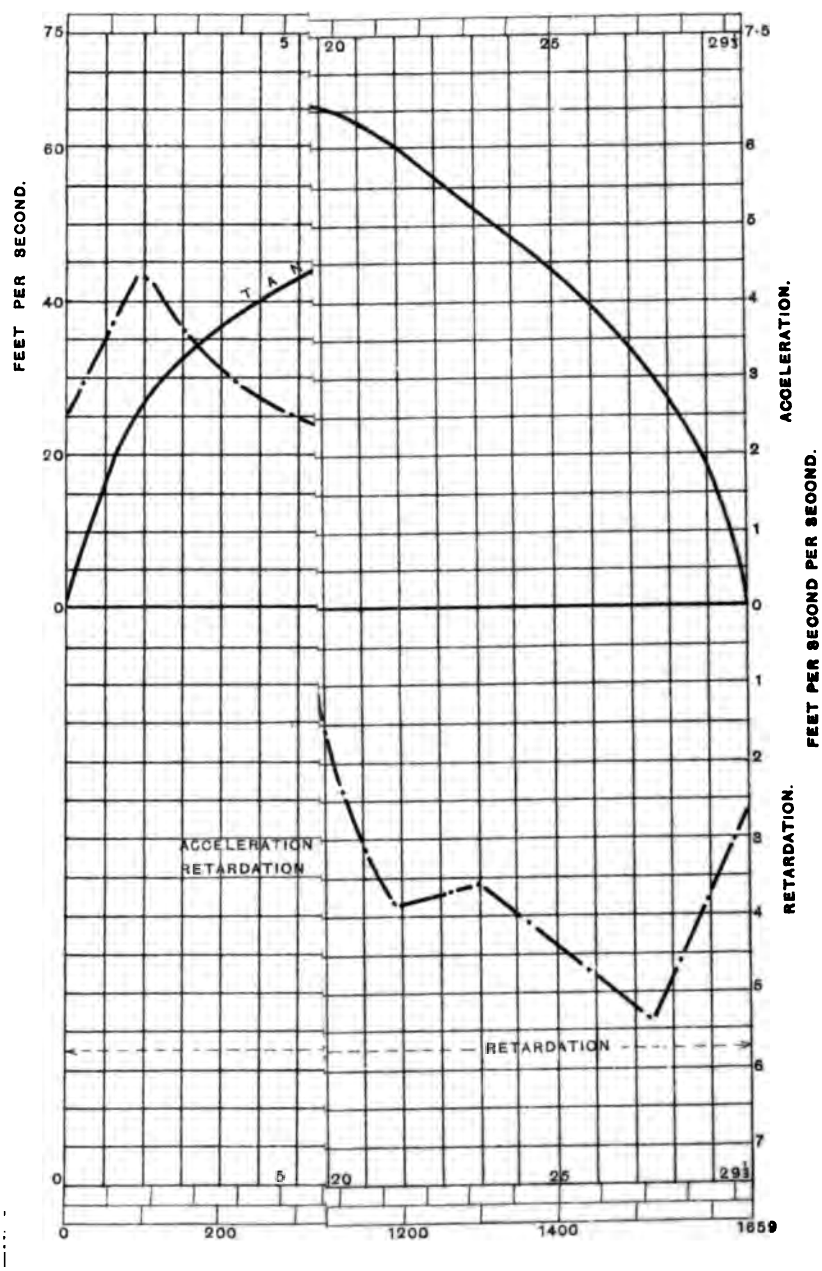
M.



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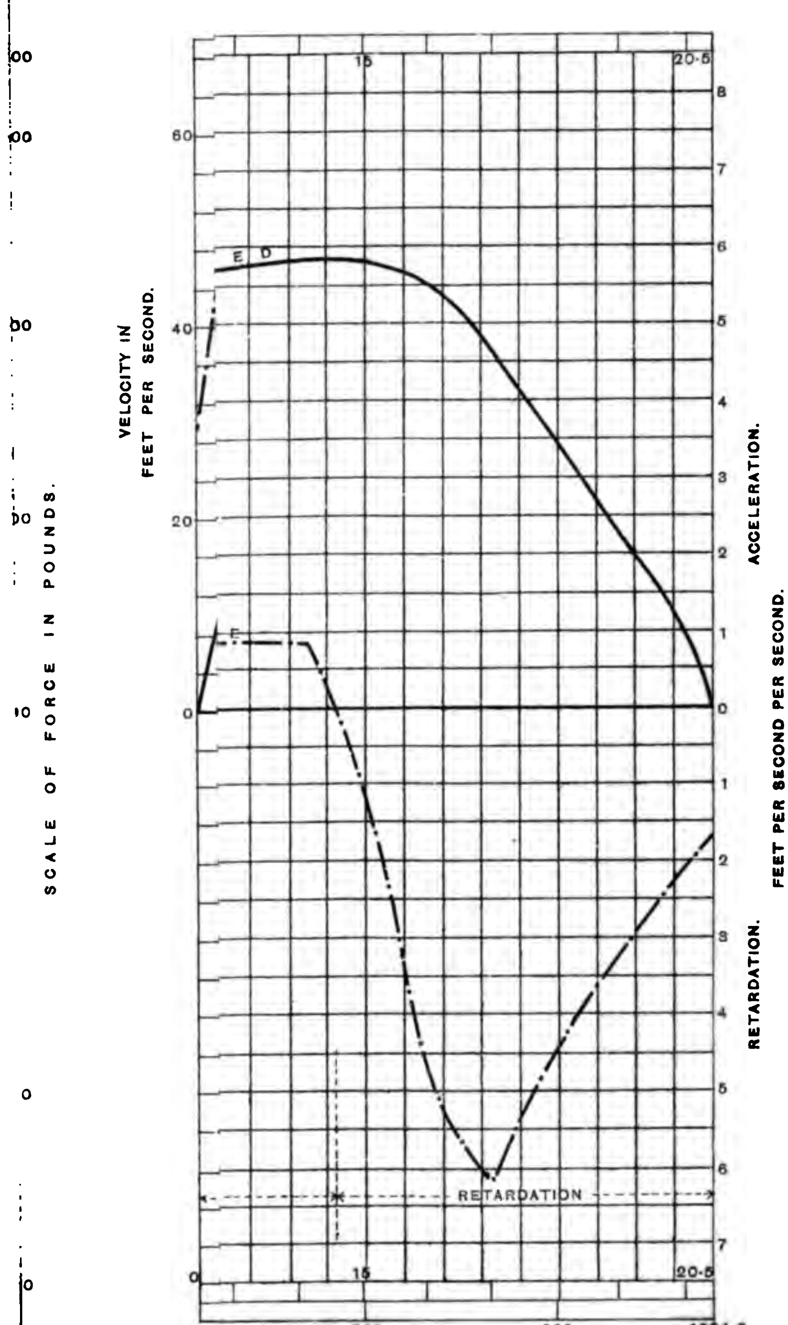
WINDING-PL

AGRAM.



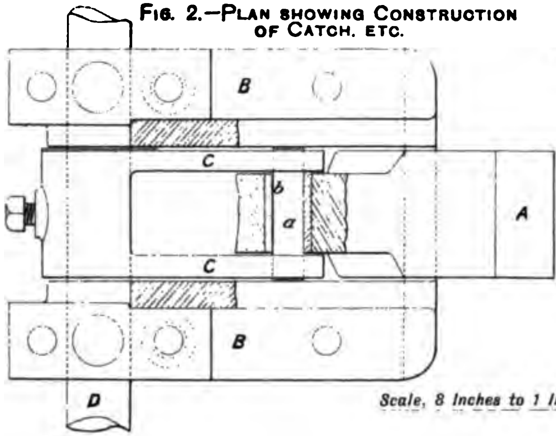
Comp.y L.td Newcastle upon Tyne.

The Institution of Mining Engineers
Transactions, 1907-1908.

To illustrate Mr. Leonard R. Fletcher's Paper on "The Patent Keps under the Cages at Chanters Pit, Atherton Collieries."

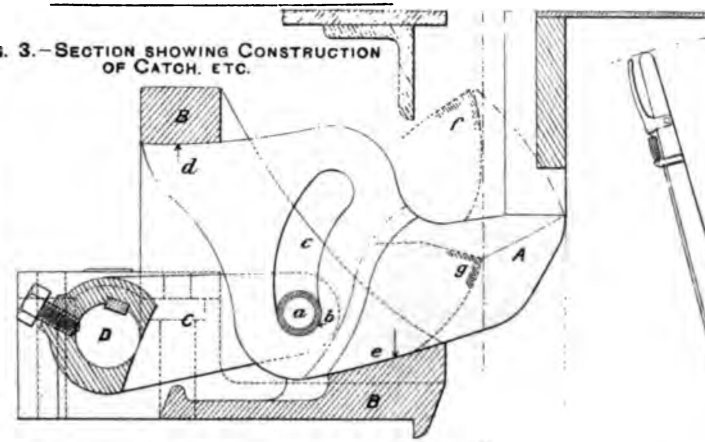
Vol. XXXV, Plate XXXII.

FIG. 2.—PLAN SHOWING CONSTRUCTION OF CATCH, ETC.



Scale, 8 Inches to 1 Inch.

FIG. 3.—SECTION SHOWING CONSTRUCTION OF CATCH, ETC.



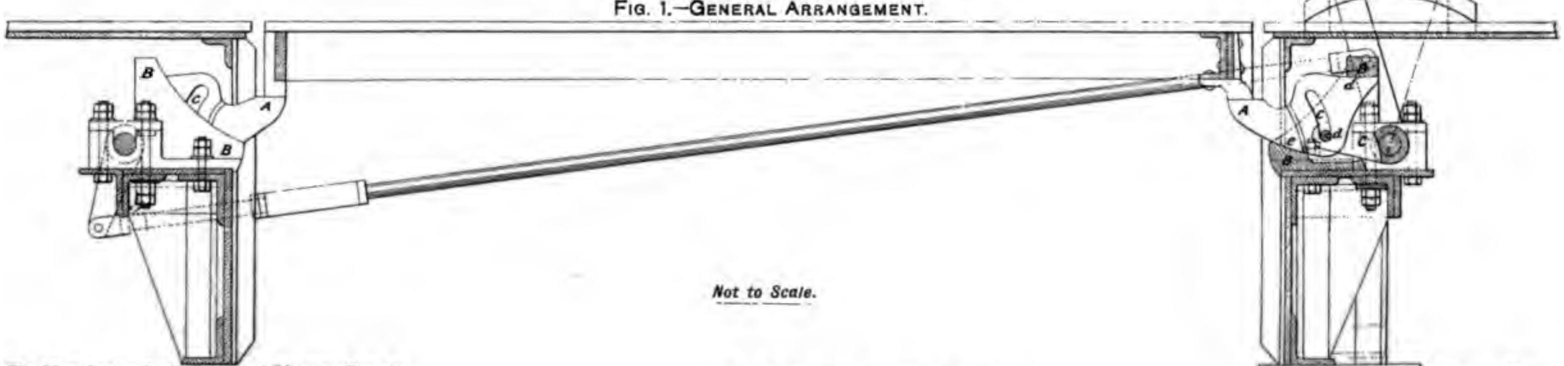


FIG. 1.—GENERAL ARRANGEMENT.

Not to Scale.

The Manchester Geological and Mining Society
Transactions 1907-1908.

Andw Reid & Compy Ltd Newcastle upon Tyne

Vol. XXX, Plate X.

The Institution of Mining Engineers
Transactions, 1907-1908.

To illustrate Mr. T. H. Wordsworth's Paper on "The Lee Safety-appliance for Cages."

Vol. XXXV. Plate XXXIII.

Fig 1. Side Elevation.

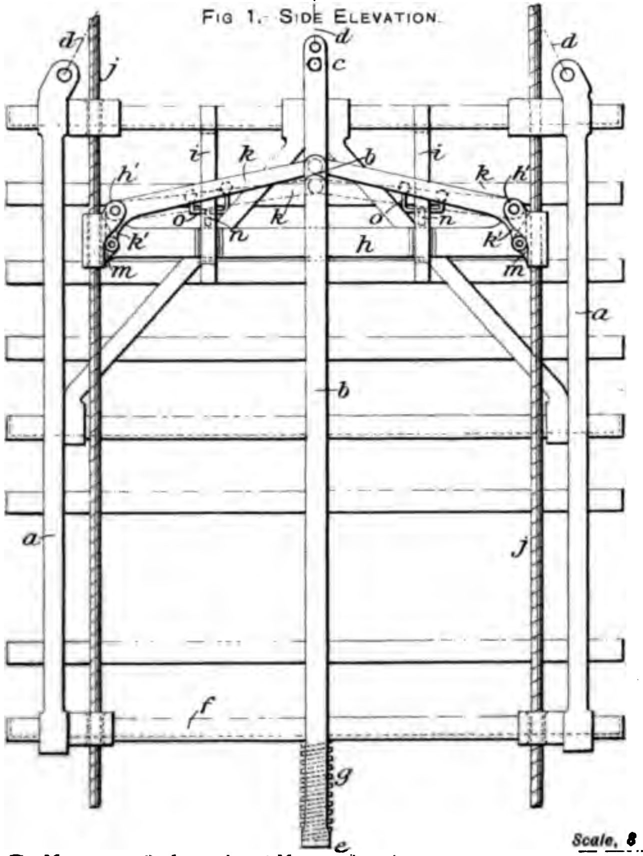
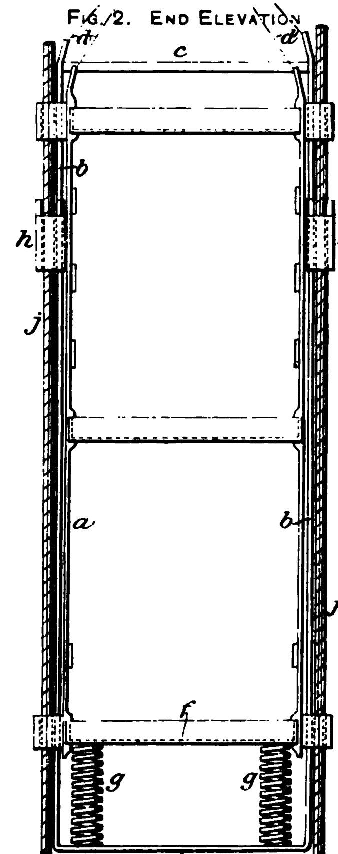


Fig. 2. End Elevation



Scale, 8 Feet to 3 Inches.

Fig 3.

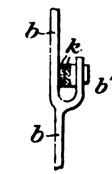


Fig. 4.

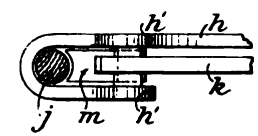
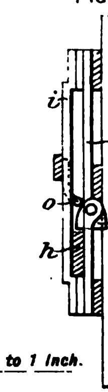


Fig. 5



Scale, 8 Inches to 1 Inch.

The Manchester Geological and Mining Society
Transactions, 1907-1908.

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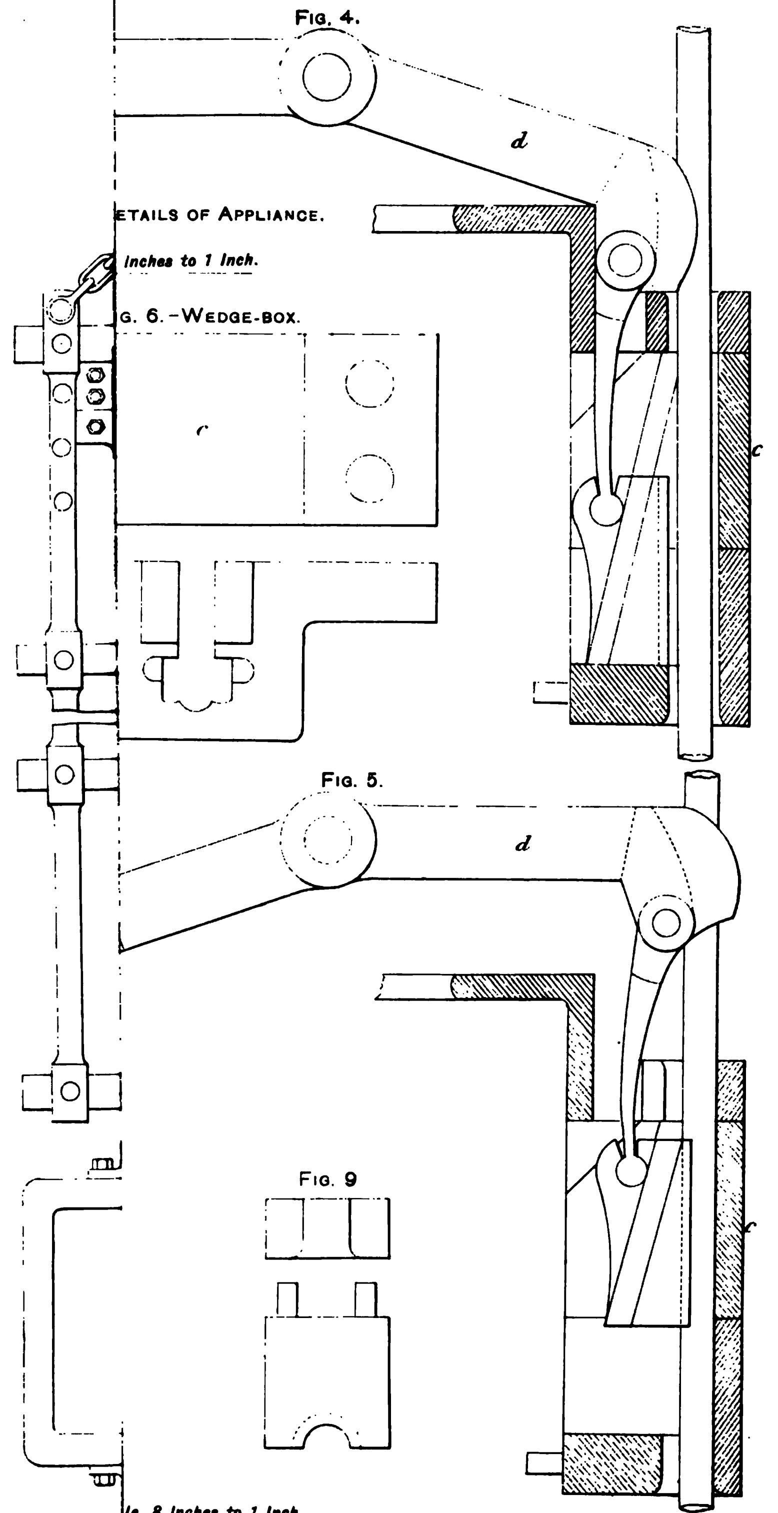
Vol. XXX. Plate XI.

[redacted]



The Manch...le, 8 Inches to 1 Inch.

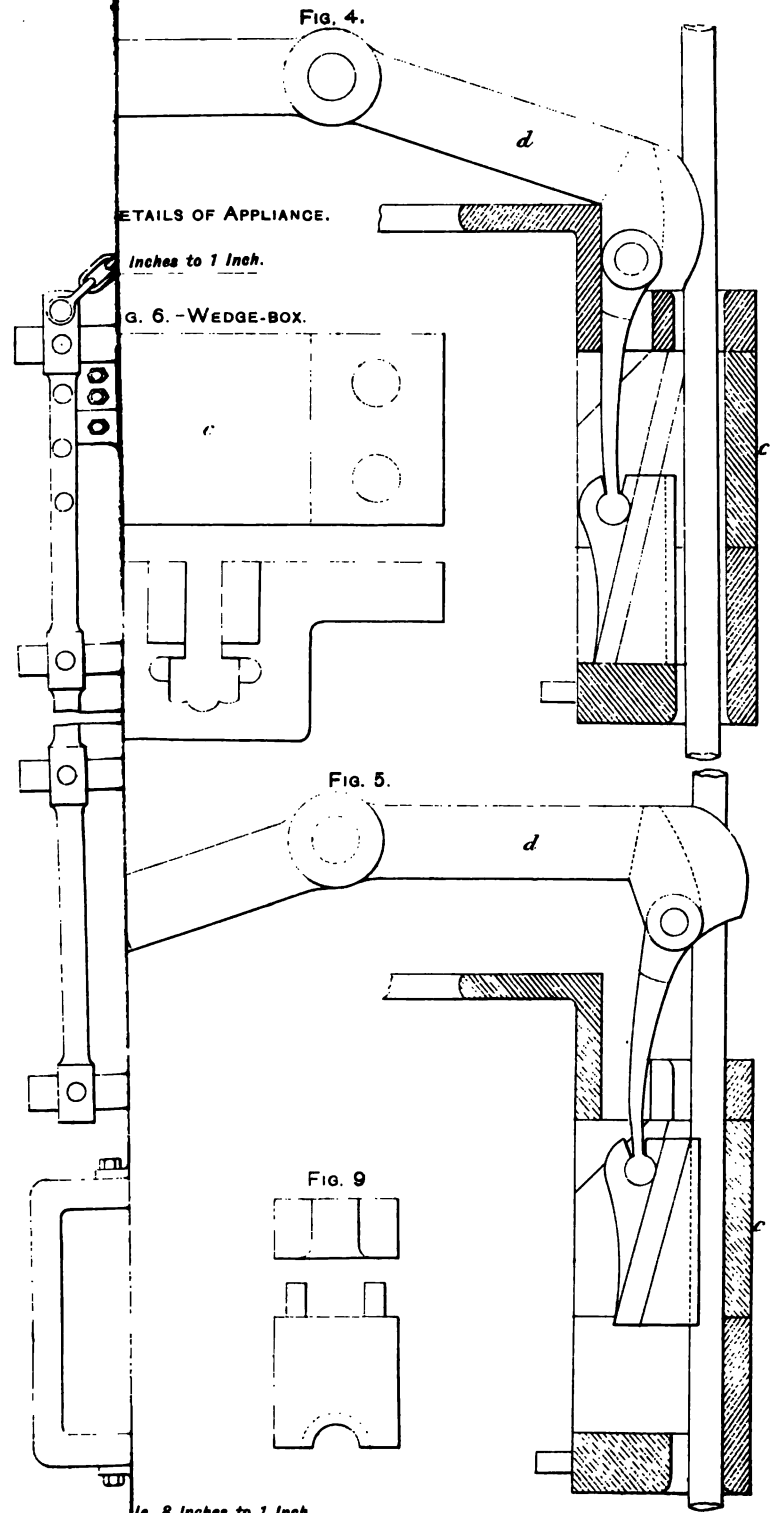


FIG. 4.
d
...ETAILS OF APPLIANCE.
... Inches to 1 Inch.
...G. 6. -WEDGE-BOX.
c
c
FIG. 5.
d
c
FIG 9